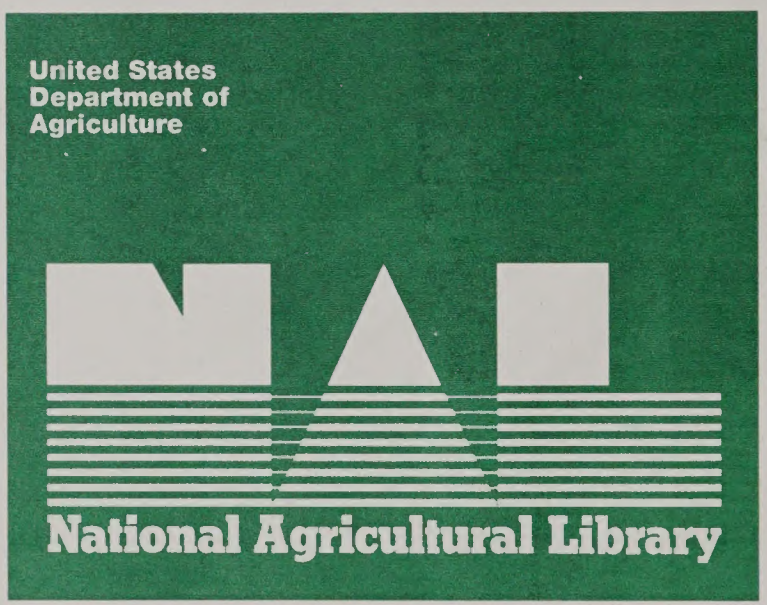
A National Program of Research for

CORN AND GRAIN SORGHUM

Prepared by

A JOINT TASK FORCE OF THE
U. S. DEPARTMENT OF AGRICULTURE
AND THE STATE UNIVERSITIES
AND LAND GRANT COLLEGES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FOREWORD

The United States Department of Agriculture and State Agricultural Experiment Stations are continuing comprehensive planning of research. This report is a part of this joint research planning and was prepared under recommendation 2 (page 204, paragraph 3) of the National Program of Research for Agriculture.

The task force which developed the report was requested to express their collective judgment as individual scientists and research administrators in regard to the research questions that need to be answered, the evaluation of present research efforts, and changes in research programs to meet present and future needs. The task force was asked to use the National Program of Research for Agriculture as a basis for their recommendation. However, in recognition of changing research needs it was anticipated that the task force recommendations might deviate from the specific plans of the National Program. These deviations are identified in the report along with appropriate reasons for change.

The report represents a valuable contribution to research plans for agriculture. It will be utilized by the Department and the State Agricultural Experiment Stations in developing their research programs. It should not be regarded as a request for the appropriation of funds or as a proposed rate at which funds will be requested to implement the research program.

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This report has been prepared in limited numbers. Persons having a special interest in the development of public research and related programs may request copies from the Research Program Development and Evaluation Staff, Room 318-E Administration Bldg., USDA, Washington, D.C. 20250.

February 1969

PREFACE

Corn and Grain Sorghum Research Needs Through 1977

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SUMMARY

CORN AND GRAIN SORGHUM TASK FORCE

The changing patterns of corn and grain sorghum production are a part of broad technological changes which have occurred within Agriculture over the past 40 years. These changes require periodic assessments of both problems and priorities.

The development and utilization of hybrid seed has involved the joint efforts and close cooperation of public and private institutions. The task force report presupposes this same type of cooperation will continue and the research needs projected represent only those segments for which public institutions should accept responsibility.

Agricultural technology has changed and new problems have arisen more rapidly than supporting research information. A few illustrations will point up the general problem. Stalk rots have become of increasing importance in the Corn Belt and the older forms of resistance are no longer adequate. Virus diseases are of increasing importance in both corn and sorghum and adequate sources of resistance are not yet available. The rapid spread of the corn root worm and the 1968 outbreak of the greenbug on sorghum illustrates the inadequate state of current knowledge concerning insect pests and methods for their control.

The guiding philosophy in developing the RPA's and the SMY projections (See table "Scientific Man Year Allocations") has been to provide a more basic approach to all aspects of corn and grain sorghum production. Increased information on host physiology will provide information useful in increasing breeding operations or for an understanding of insect or disease resistance. Similarly a knowledge of genetic variability and life history will permit of more efficient assessment of potential destructiveness of disease and insect pests and aid in the development of suitable control measures. A clearer understanding of the mechanism of herbicidal action is required for the development of more specific and safer herbicides. More attention needs to be given to the coordination and evaluation of all aspects of the production system including the evaluation of new hybrids, the various weed, insect, and disease control practices, the development and evaluation of machinery and handling practices, the nutritional and industrial uses and potential of these grains and the associated economic considerations. This integrated approach can be achieved only through cooperation and integration among the discrete RPA's and their subdivisions.

Scientific Man Year Allocations, Corn and Grain Sorghum

RPA	Scientific Man-Years 1966	1972	1977
207	48	68	87
208	30	49	69
209	14	33	42
307	131	153	188
308	12	16	27
309	1	6	9
405	6	8	8
406	7	32	35
407	68	58	63
408	18	21	26
501	-	2	3
504	7	14	17
Total SMY	342	460	564

INTRODUCTION

Assignment: Corn and grain sorghum research in the following Research Problem Areas were assigned to this Task Force:

RPA 207 Control of Insect Pests
RPA 208 Control of Insect Diseases
RPA 209 Control of Weeds
RPA 307 Improvement of Biological Efficiency
RPA 308 Mechanization of Production
RPA 309 Systems Analysis in Production
RPA 405 Development of Types with Improved Nutritional or Industrial Use
RPA 406 New and Improved Food Products
RPA 407 New and Improved Feed and Industrial Products
RPA 408 Quality Maintenance in Marketing
RPA 501 Improved Grades and Standards
RPA 504 Marketing Efficiency

Within the general framework of the Long-Range Study, the Task Force was instructed to indicate areas of research which need emphasis, and to determine the most efficient procedures for organizing and carrying out the specific research involved.

Corn and sorghum represent our most valuable field crops. The combined farm value of these crops exceeds that of any other group including all other cereals, cotton, tobacco, sugar crops, and oilseeds. The farm value of corn and sorghum is approximately equal to 35% of all field crops combined. Using another standard of reference, the annual value of the corn and sorghum crop equals the value of the annual steel production of the United States.

Increase in corn production is related to the adoption of hybrids and associated improvements in cultural and production practices. Using the 1928-32 pre-hybrid years as a base, the acreage devoted to corn has decreased by approximately 50 percent and production has increased to 175 percent. Grain sorghum has followed the same general pattern but with a different time scale. Hybrid grain sorghums did not come into extensive commercial use until 1957.

This unique record of increasing agricultural efficiency is based on an equally unique pattern of cooperation. With the initiation of the corn breeding programs in the 1920's, close cooperation developed between USDA and the State Agricultural Experiment Stations. Many of the programs were staffed by USDA with the State providing land, local facilities, and a portion of the operating expenses. Where this organizational pattern did not exist, other patterns of cooperation involving the free exchange of ideas and breeding stocks became the accepted practice. With the increasing adoption of hybrids by farmers, the Hybrid Seed Industry expanded and came to play the dominant role in the production and distribution of hybrid seed to the farmers. Close cooperation persists between these three groups, and every effort should be made to maintain the present relations. This same cooperative arrangement exists in areas relating to production, e.g. Agricultural Engineers and machinery manufacturers, soil fertility specialists and the Fertilizer Industry, etc. Under these cooperative arrangements private industry assumes the primary responsibility for the development and distribution of commercial hybrids, the development of new machinery or the production of new formulations of fertilizers. The public institutions have primary responsibility for research in problem areas requiring a multi-disciplinary approach.

The development of the RPA's recognizes the responsibilities inherent in the existing pattern of cooperation and the research approaches outlined are predicted on the continuation of such cooperation in essentially its current form.

This Task Force is concerned with the problem of obtaining adequately trained and oriented manpower to carry out the recommendations. This task is the responsibility of the State Institutions. Specifically, expansion of pre and post-doctoral studies at the various Land Grant Universities and State Experiment Stations throughout the country, is the most economical and feasible

program for providing the technical personnel that will be required for implementation of the projected work. Such expansion is considered imperative and will further the establishment of centers of excellence in specific subject matter areas with appropriate research concentrated at such locations.

Situation: The spectacular increases achieved in corn and grain sorghum production, over the past 20 years, have resulted from the development of varieties with a higher yield potential, and from improved production practices. The percentage increase in production is substantially higher than the increase in population growth. Further improvements are needed in both yield potential and production practices to provide an increasing level of efficiency of production, and a more adequate income to Agriculture. Both crops have the potential for an increased export market and industrial utilization.

In the past, primary emphasis has been placed on yield. The yield increases which have been obtained are a reflection of the magnitude of the effort expended rather than the efficiency of the methods used. Further yield increases can be obtained under the present systems but in decreasing increments relative to the effort expended. An increase in efficiency of breeding operations appears unlikely unless we make full use of the accumulated genetic information together with the development of a detailed knowledge of plant physiology. This is potentially feasible since the genes are the source of information that code for the kinds and amounts of enzymes and enzyme systems that establishes the physiology of the plant. Knowledge of metabolism constitutes the base upon which knowledgeable research on production, product quality and resistance to insects and disease can be initiated. In brief, detailed knowledge of the genes and their products provides insight into the physiology that will let man control plants.

An analagous situation prevails for RPA 207 and 208 (Insect control and diseases). New production practices have created new problems requiring far greater emphasis on insect and disease resistance, and on the physiology of the plant. Strains of the corn rootworm, resistant to the chlorinated hydrocarbons, are rapidly spreading eastward. The southwestern stalk borer has invaded half of the Southern States east of the Mississippi. Sources of resistance to the common stalk rots, which were adequate under earlier cultural and management practice, no longer provide the protection needed when grown at closer spacings with increasing quantities of fertilizer. An expanded effort is needed in RPA 207 and 208 to maintain the status quo. A greatly expanded effort will be required to effect material reduction in losses from disease and insect pests. Such work should be broad based, taking into consideration the genetics, life history, and physiology of both parasite and host. It would appear that no real gains can be realized without such a comprehensive approach.

The current level of research is inadequate to provide answers to current production and utilization problems. Increases in efficiency of production and utilization will require an expanded research effort. Production practices represent an interacting system. Changes in any one practice may profoundly

affect the efficiency of other practices thus requiring a continuing evaluation and modification of the individual components of the entire system. Subdivision of the entire research problem area into a series of discrete RPA's may be necessary and useful but it tends to obscure the necessity of a fully coordinated program. An attempt has been made to minimize the artificiality of such sub-divisions by indicating for each RPA sub-division the more closely related subdivisions of other RPA's.

Such listings will serve little useful purpose, however, unless considerable effort is expended to ensure the necessary coordination and cooperation.

Recommendation 1

The Task Force recommends protection research effort be distributed among 18 specific objectives within the 3 RPA's (207, 208, 209) dealing with crop protection. An expanded research effort is required to prevent mounting losses. The general trend toward increasing productivity has involved increased plant populations, heavier fertilization rates and, for an increasing fraction of the acreage, continuous cropping. These changes in plant environment have contributed to increasing losses from insects, diseases, and weeds. Stalk rots are becoming an increasingly important problem. Current losses are undoubtedly substantially greater than estimated in "Losses in Agriculture" (USDA Handbook No. 291). Satisfactory levels of control are available for only a few of the important insect pests. Many weeds of importance cannot be controlled by current herbicides, cultivation or their combination. An increased effort will be required to prevent further increases in losses and a greatly expanded effort will be necessary to effect any substantial reduction in losses.

Increases in production have been achieved through a combination of elements; better hybrids, improved production practices, and better farm machinery. There has been little coordination, however, between these separate specialty areas. The development of improved hybrids has been largely empirical. Our knowledge of physiological processes affecting growth and yield is quite inadequate. Knowledge as to the extent and mechanisms of genetic control of such physiological processes is extremely limited. Expansion and redirection of research in these areas is necessary to provide the basis for increases in efficiency of agricultural production. Machinery developments have been on an item basis. Only limited attention has been given to each item as an efficient component of the whole farming system. Even less attention has been given to a restructuring of the plant to facilitate more efficient harvesting procedures.

Recommendation 2

The Task Force recommends that research work in the production area (RPA's 307, 308, 309, 405) be reoriented to provide greater emphasis to: (1) development of basic theory in and the interrelations between genetics and physiology to provide for greater efficiency in the development of improved types, (2) the design of equipment items as

integral components of a complete system of production and harvest, and (3) a more complete delineation of the individual components, and an evaluation of these in relation to maximizing the efficiency of the total production system.

An increasing percentage of the production of corn and grain sorghum is moving into trade channels and a decreasing percentage is used directly as livestock feed on the farm where it is produced. The proportion of these crops used for industrial processing has little more than kept pace with population growth. Harvesting at higher moisture contents, which requires the use of artificial drying, may modify the quality of the crop for either nutritional or industrial uses. There is need for further work to minimize losses in quality from such practices and to effect increases in the nutritional and industrial value of these grains.

Recommendation 3

The Task Force recommends that the current emphasis on search for new or more efficient industrial uses be maintained.

The efficient production, marketing and utilization of corn and grain sorghum, and their by-products is dependent upon research additional to the RPA's specifically covered in this report. The preservation and expansion of foreign markets (RPA 601) is of vital concern. Exports of feed grains in recent years has expanded at a faster rate than production. A further expansion of exports appears likely and a strong developmental program should be maintained. The protection of production and products is of universal concern. Therefore research in RPA 702 (Protection of Foods) and RPA 901 (Pollution) are directly related to the objectives of this task force.

RPA 207 - Control of Insect Pests

Introduction

Major crops such as corn and sorghums which are produced under widely different environmental conditions present many interrelated problems in which insects are commonly involved. More than 400 species of insects cause over $550 million damage to corn and sorghum each year in the United States. An additional $100 million is spent on control. Other insects cause indirect damage by transmitting corn or sorghum diseases. Additional major pests which could be accidently introduced at any time attack these crops in other parts of the world.

The introduction and use of organic insecticides in the last two decades and the development of better equipment for applying them have been important factors in the improved control of corn and sorghum insects. However, the continued public opposition to the use of insecticides, the many complex residue and other hazard problems, and the growing number of insects that have developed resistance to insecticides, have emphasized the need to investigate all possible means for control of destructive insects. Many of the benefits

of research to develop more effective insect control cannot be quantified specifically. The development of non-chemical control methods or more efficient chemical control methods would reduce the need for insecticides and thus reduce the hazard to beneficial insects and wildlife, and reduce air, food soil, and water pollution. Benefits from such developments can not be expressed in dollars. Other research outlined under RPA 207 would reduce the cost of production and increase yield and quality.

CONTROL OF INSECT PESTS RPA 207

TITLE: Biology, Taxonomy, Physiology and Nutrition. RPA 207-A.

SITUATION: The various elements of the environment may unleash the tremendous reproductive potential of insects. Therefore, we need to know more about the interaction of the environment with insects so that we may make more accurate predictions of outbreak potentials to save growers money and avert disaster. Knowledge of insect classification, life cycle, migration, host range, and other biological, ecological, and physiological characteristics is essential to develop satisfactory chemical, cultural, bilogical, and other methods of control. Only through a thorough knowledge of a pest's life cycle can one hope to aim control measures effectively at its most vulnerable stage. Accurate determination of insect species is a key to the published works and the foundation for basic and applied entomological research.

OBJECTIVE: To determine the life history, distribution, abundance, damage, nutritional requirements, and other biological, morphological, physiological, and ecological characteristics of insects which may be of value in developing control measures.

RESEARCH APPROACHES:

A. Conduct taxonomic studies on all developmental stages of insects attacking corn and sorghums in all areas of the world as a foundation of valid identification procedures.

B. Determine mating, feeding, migration, alternate host plants, and population dynamics of major corn and sorghum insects and use this information to develop control measures.

C. Determine the physiological processes of insect development and interpret and evaluate such information as a possible means to develop control measures.

D. Determine the variation in ecological, physiological, and morphological characteristics of insect species from different geographical populations.

E. Determine the cause of insect population fluctuations.

F. Determine the genetic variability within the insect population.

G. Determine the effect of various insect populations at different times and under different growing conditions on yield and quality of corn and sorghums and determine the economic injury threshold.

H. Use genetically similar resistant and susceptible host strains (isogenic lines) or chemical control to determine extent and type of plant injury caused by insects.

I. Develop artificial rearing media for insects so that nutritional requirements can be refined.

J. Develop process equipment and environmental control for mass rearing, handling, and distributing insects used in host plant resistance or biological control methods.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: The benefits from this activity are related to 207 B, C, D, E, and F, and cannot be quantified specifically. The information obtained is basic and essential to facilitate and speed the gains obtained from other research and may prevent losses that would otherwise occur.

RESEARCH EFFORT:

T F RECOMMENDATIONS	
1972	1977
15	19

TITLE: Control of Insects Through the Development of Host Resistance. RPA-207-B.

SITUATION: One of the most economical and desirable ways to control insects is through the use of germ plasm which resist their attack. Resistance can be combined with other desirable qualities and maintain control without cost to the grower and without creating insecticidal problems which at times may upset nature's balance between pest insects and their natural enemies. Progress has been made in developing corn and sorghum inbreds and hybrids which are resistant to a few insects, but resistance to other insects is inadequate. Present gains may be lost if inadequately tested or susceptible sources of germ plasm are used in breeding programs or if insect strains develop which can attack inbreds or hybrids which are now classified as resistant. Information on new sources of resistance, methods of breeding and producing resistant inbreds and hybrids, are required, so that resistant hybrids can be produced more rapidly and efficiently.

The reaction of available corn and sorghum germ plasm to foreign insects that might be accidently introduced into the U.S. needs to be determined. Some work on this nature is being done under PL 480 projects and by various international research organizations, but these programs are confined to limited areas. Resistant hybrids are often a part of integrated control methods, since hybrids with only a moderate degree of resistance can be used to supplement biological, cultural, chemical, or other control methods.

OBJECTIVE: To identify and evaluate the insect resistance of corn and sorghum germ plasm from various sources, determine the cause of such resistance, the mode of inheritance, and determine the most efficient breeding procedures to transfer insect resistance to productive well-adapted hybrids.

RESEARCH APPROACHES:

A. Evaluate corn and sorghum germ plasm including exotic varieties and wild relatives for resistance to major insects that occur in the U.S. and foreign countries.

B. Develop improved methods for producing insects for use in manual infestations to determine the relative resistance of corn and sorghum germ plasm.

C. Determine the chemical, physiological, or morphological nature of resistance and the inheritance of these factors.

D. Determine the relative efficiency of various breeding methods for transferring insect resistance to inbred lines.

E. Develop insect resistant synthetics and other source populations from which superior inbred lines may be isolated.

F. Combine resistance to two or more insects into commercially usable genetic stocks.

G. Study the inheritance of host reaction to insects and insect virulence to host plants.

H. Determine the presence and the relative abundance of different physiological races of insects before and after resistant hybrids have been released.

I. Determine the effect of resistant hybrids after they are released on the over-all population of the insect in the area.

J. Determine degree of resistance that is economically satisfactory.

K. Develop isogenic lines with and without insect resistance so that the nature and effect of resistance can be more accurately determined.

L. Determine the factors responsible for development of insect biotypes which react differently to resistant varieties.

M. Determine the value of low levels of insect resistance when combined with chemical or other control methods.

N. Determine the effect of insect resistance on the parasites and predators of the insect pest involved.

O. Determine the effect of environmental factors on resistance.

P. Coordinate findings with RPA 207-D, 208-B, 307-C, and 405-A.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Probably one-half of the $550 million annual insect loss to corn and sorghums could be prevented if hybrids could be developed resistant to the major insects. Also see Potential Benefits under Introduction for RPA 207.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
17	21

TITLE: Effect of Cultural Practices on Insect Population and Control. RPA 207-C.

SITUATION: The practices involved in corn and sorghum culture are presently in a highly dynamic state involving trends toward monoculture, higher plant population, increased commercial fertilizer application, narrow rows, use of herbicides and minimum tillage, irrigation, etc. representing an intensified agriculture. Frequently, a slight modification in the growing of a crop may influence insect damage. A thorough knowledge of the life history of a pest species is essential in developing cultural control methods. Crop rotation may be effective for insects with a restrictive food habit or those having limited power of migration. Fall plowing or crop refuse destruction may kill insects hibernating in or on soil or in crop refuse. When cultural control practices are also desirable agronomic practices, they are usually readily adopted. However, when they are poor agronomic practices, it is necessary to carefully weigh the advantages and disadvantages before these methods should be recommended. A change in cultural practices to control one insect may cause another insect which has not been important to become more prevalent. Changes in insect populations which accompany changes in management practices must be detected, and methods must be developed immediately to control these insects. Cultural practices alone may not give completely satisfactory insect control, nevertheless they are often important in minimizing injury, and should be considered in any area-wide integrated control program. If entomological research on cultural control is to keep pace with agronomic production research, theentomologists must work cooperatively with all scientists who are concerned with corn and sorghum production.

OBJECTIVE: To determine the effect of management practices on insect population and to identify changes in insect incidence associated with new management practices.

RESEARCH APPROACHES:

A. Study the effect of various crop rotation, tillage, and crop residue management practices on the insect population.

B. Evaluate the effect of time, rate, and method of planting, seed bed preparation, and fertilizer application, and irrigation practices on insect infestations.

C. Determine the effect of plant characteristics such as height, early or late maturing, high or low protein, multiple ear, excessive tillering, on insect population and damage.

D. Determine if insect biotypes might develop due to a change in cultural practices.

E. Identify changes in insect incidence due to acceptance of new management practices.

F. Determine changes in ecology and micro-environment from changes in management practices and how these affect insects.

G. Coordinate findings with RPA 208-C, 209-F, 307-E, and 308-A.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Permit new management practices to be used without increasing insect damage. Also see Potential Benefits under Introduction for RPA 207.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
5	6

TITLE: Biological Control. RPA 207-D.

SITUATION: Biological factors such as parasites, predators, and diseases often play a major role in reducing insect populations. Some of our most injurious insects on corn and sorghums have been accidently introduced from foreign countries. The increased world trade and travel makes it almost impossible to prevent additional accidental introductions. Since introduced pests usually arrive without their natural enemies, some that were of little economic importance in their native habitat have become very destructive in their new environment. There is need to collect, propagate, and introduce parasites, predators, and insect pathogens from the insect's native home and disseminate them throughout the range of the pest in the United States. Research being conducted in some foreign countries under PL 480 programs has been especially effective in evaluating and introducing parasites and predators, but these research programs are confined to limited areas.

Many of our injurious insects on corn and sorghums have a variety of native parasites and predators, attacking them throughout their seasonal history. Some of these factors appear to be quite effective. However, little is known about the biology and ecology of these control agents.

There is need to thoroughly survey the parasites and predators of corn and sorghum insects and determine which ones exhibit potential as effective control agents. For those agents which do exhibit potential use, subsequent biological and ecological studies in the laboratory and field should be conducted to determine how they might be best utilized and applied in our pest control program. In some instances a slight ecological manipulation may be all that is required to throw conditions in favor of the natural enemy. In other instances, it may be feasible to mass rear and release the control agent to suppress the pest population. Under some conditions naturally occurring diseases may terminate what appeared to be an extensive insect outbreak. There is need for research to determine if such insect pathogens can be propagated in the laboratory and disseminated by man to control these insects.

OBJECTIVE: To determine the fauna and ecology of parasites, predators, and insect pathogens attacking pests of corn and grain sorghums and to devise techniques for developing these agents for control programs.

RESEARCH APPROACHES:

A. Search for parasites, predators, and pathogens of insects in their native home and when found evaluate, propagate, introduce, and disseminate these agents in the area where the host insect occurs in the United States.

B. Determine the biology and evaluate the effectiveness of both native and introduced parasites, predators, and diseases for the control of major insects attacking corn and grain sorghums.

C. Evaluate the effect of insecticides and various cultural practices on the parasite and predator population.

D. Determine effective levels of natural occurring and introduced biological control agents so we are better able to give advice on other control methods such as use of insecticides.

E. Develop insecticide resistant strains of parasites and predators for release.

F. Develop techniques for mass production and release of parasites, predators, and insect pathogens, and evaluate various time and rate of release of these organisms individually and in combination for field control.

G. Combine the use of biological factors with various other techniques into integrated insect control systems suitable for use by corn and grain sorghum producers.

H. Coordinate findings with RPA 209-F.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: See Potential Benefits under Introduction for RPA 207.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
9	13

TITLE: Chemical Control. RPA 207-E.

SITUATION: Discoveries of new synthetic insecticides and improved methods of applying them have made it practical to use insecticide to control many insects attacking corn and grain sorghums. Private industry has assumed the major responsibility for developing new and more effective synthetic insecticides, but it remains the responsibility of the public agencies to determine their effectiveness for control of specific insects on specific crops. Several insects have become resistant to insecticides that formerly gave satisfactory control. Some insecticides reduce the population of beneficial parasites and predators and may be toxic to wildlife. Although tolerances have been set on several insecticides for use on corn and grain sorghums, these tolerances may not be accepted in all foreign countries thus affecting the export market. Because of these factors, research is needed to find materials that possess maximum biological activity against the target insect with a minimum of biological activity against man, animals, and other useful organisms in the environment. Special emphasis should be devoted to a search for insecticides which do not accumulate in plant and animal tissues. Since many residue problems arise from insecticide drift to non-target areas, there is need for improved formulation and insecticide application equipment, to reduce drift and obtain greater precision in application.

OBJECTIVE: To develop more effective and economical chemical control methods that will leave no objectionable residues, cause minimum reduction in beneficial insects, cause a minimum of air, soil, and water pollution and be non-hazardous to higher animals.

RESEARCH APPROACHES:

A. Evaluate insecticides for control of corn and grain sorghum insects.

B. Test different insecticide formulations, rates, and time of application.

C. Devise critéria to use in making decisions of the need for and time of application of insecticides for insect control.

D. Evaluate recommended insecticides against major corn and grain sorghum insects from various locations to detect if the insects are becoming resistant to insecticides.

E. Determine the nature or cause of insect resistance to specific types of insecticides.

F. Develop methods for insect control using combinations of an insecticide with insect attractants, plant attractants or feeding stimulants.

G. Evaluate the effect of insecticides on beneficial insects and wildlife.

H. Determine phytotoxicity and compatibility of pesticides.

I. Determine insecticide residues, and degradation in the plant and soil.

J. Develop design--performance criteria, and techniques for application of insecticides to improve insect control, reduce amount of chemicals required and reduce amount of drift.

K. Coordinate findings with RPA 208-C, 209-B, 209-D, 308-A.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: See Potential Benefits under Introduction for RPA 207.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
16	18

TITLE: Insect sterility, attractant and other new approaches. RPA 207-F.

SITUATION: Several new approaches to insect control offer good possibilities. The use of insects for their own destruction by employing the sterility principles has been demonstrated successfully for controlling the screwworm and certain tropical flies. It has been shown that when sterile insects are released and compete with the normal insects for reproduction, the biotic potential of the natural population can be greatly reduced. Insects are attracted to various stimuli, including specific substances in host plants, to natural products such as sex attractants produced by insects themselves, and to light, sound, and other electromagnetic radiations. The use of chemosterilants in conjunction with attractants that will lure insects in large numbers has good possibilities for controlling some insects. The use of natural or synthetic hormones as a possible means for development of methods to interfere with or interrupt insect growth and reproduction needs to be investigated. These various new approaches need to be considered in any integrated control program.

OBJECTIVE: To investigate methods of sterilizing insects, isolate attractants, hormones, or other biological active materials and use this information in developing control methods.

RESEARCH APPROACHES:

A. Determine if it is feasible to apply the concept of area population suppression for the control of the major corn and sorghum insects utilizing the principles developed in sterile male release technique, attractants, genetic lethals, etc.

B. Determine if insects have genetic systems that can be utilized to reduce viability or fecundity, and mass release these types.

C. Determine if variation between insect strains or races can be used in manipulation of genetic characteristics that can be used for control.

D. Isolate attractants from plants or insect sex attractants and investigate the feasibility of using these for control.

E. Evaluate light, sound, and other electromagnetic radiations as insect attractants.

F. Evaluate the effect of natural or synthetic hormones on the growth and reproduction of insects.

G. Combine the use of these new approaches with various other techniques into integrated insect control systems suitable for use by corn and grain sorghum producers.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: It might be possible to eradicate or control on an area-wide basis some of the major corn and grain sorghum insects by these new methods. Also see Potential Benefits under Introduction for RPA 207.

RESEARCH EFFORT:

T F. RECOMMENDATION	
1972	1977
6	10

RPA 209 - Control of Diseases

INTRODUCTION

Diseases annually reduce national average grain yields of corn by 15 per cent and of grain sorghum by 11 percent. When local conditions are favorable, certain diseases develop in much more destructive proportions and cause substantially greater losses. Production hazards due to disease are expected to increase as cultural practices for these two crops intensify. Continued effort in disease control at the present level is inadequate to prevent losses from becoming even greater. A greatly expanded research effort is needed to substantially reduce current losses. The work must be broadly based, comprehensive, and multi-disciplinary. Close cooperation with private industry must be maintained. The research is detailed in the following five problem areas: A) Identification, etiology and development of corn and grain sorghum diseases, B) Genetics and physiology of plant-pathogen interactions and control of disease through genetics and breeding, C) Control of disease through the use of pesticides and management practices, D) Storage diseases and relationship of disease to quality, and E) Identification, etiology and control of foreign diseases that might be damaging to American corn and grain sorghum.

CONTROL OF DISEASES RPA 208

TITLE: Identification, etiology and development of diseases. RPA 208-A.

SITUATION: Numerous fungi, bacteria, viruses, nematodes, and parasitic seed plants are known to attack corn and grain sorghum and cause reductions in yield and quality. Other losses are caused by non-infectious agents. In recent years corn, and to a lesser extent grain sorghum, has been severely damaged by viruses that have heretofore been confined to other plants. Kernel red streak, caused by an insect toxin, is now a prevalent disorder. Within the last decade, a downy mildew disease, previously found only in Africa and Asia, was identified and shown to be spreading in the U.S. Several pathogens have the potential of causing complete destruction of the crop if not controlled. Others are capable of causing yield losses from 10 to 75 percent. A few diseases have never developed in destructive proportions. In other crops, however, minor diseases of this type have become major diseases when crop varieties and cultural conditions have appreciably changed. Recently, corn root and stalk rots have increased in prevalence and severity. Losses of 12 per cent in the North Central States are greater than national average losses in previous years. This is due in part to the prevalence of root feeding insects but predominantly to the greater use of high plant populations and large amounts of commercial fertilizers. Unless an adequate control for stalk rot can be achieved, yield increases through more intensive culture or growth of hybrids with greater yield potential will be precluded. Thus, new disease problems arise while older ones are continually changing.

OBJECTIVE: To gain a more thorough understanding of the causes of corn and grain sorghum diseases, the pathogens and agents of these crops, the factors influencing disease development, and the effects of disease on the efficiency of the plant.

RESEARCH APPROACHES:

A. Identify the pathogens and noninfectious agents causing disease and determine life cycles, host ranges, methods of transmission, spread, and infection by pathogens including viruses and nematodes.

B. Study development and survival of saprophytic stages of pathogens causing root rots, stalk rots, and other diseases.

C. Determine the external factors (environmental) affecting disease development with particular emphasis on root and stalk rots.

D. Determine the internal characteristics (biochemical, morphological, and physiological) of host-parasite interactions.

E. Determine virus movement and increase within the vector(s), and the relationship of vector movement between and within fields on the spread and development of virus and bacterial diseases.

F. Determine crops and other plants that may serve as alternate hosts of viruses, nematodes, and other pathogens of corn and grain sorghum and the significance they play in disease development.

G. Determine the effect of viruses, foliage pathogens, nematodes and insects on the development of other diseases with particular emphasis on root and stalk rots.

H. Conduct disease surveys and develop improved methods of calculating crop losses.

I. Use genetically similar resistant and susceptible host strains or chemical control to determine extent and type of plant injury caused by pathogens including viruses and nematodes.

J. Develop effective inoculation techniques for creating artificial epiphytotics to facilitate studies of injury and control.

K. Coordinate with research in RPA's 307-G and 307-H.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Information on the nature, cause, and epiphytology of disease is basic to intelligent development of proper control procedures. Therefore, the benefits from this activity are directly related to those obtained from disease control through breeding or use of pesticides and management practices.

In addition, losses that might occur through unwise changes in cultural practices could be anticipated and avoided.

The magnitude of potential benefits cannot be quantified specifically but they would be included in those of 207-B and 207-C.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
20	25

TITLE: Genetics and physiology of plant-pathogen interactions and control of disease through genetics and breeding. RPA 208-B.

SITUATION: Large reductions in yield, quality, and efficiency of corn and grain sorghum production are sustained each year as a consequence of disease attack. Fortunately, resistant hybrids now materially limit the potential destructive development of many diseases of these crops. A real danger exists, however, that present gains in genetic control may be lost if inadequately tested hybrids are put into production, if pathogens change in their virulence, or if cultural conditions change to exceed stress levels of present hybrids. Resistance to root and stalk rots and to nematodes is presently inadequate.

Inbred lines, varieties, and hybrids differ in resistance to one or more diseases. Frequently, these stocks are resistant to only one or a few diseases and are susceptible to others. In many instances sources of resistance are unsatisfactory in yield, adaptability, and other agronomic characteristics.

Resistance to a given disease can take several forms. Some forms are effective against specific strains or races of a pathogen. To these forms of resistance, genetic changes can occur in pathogens enabling them to overcome the barriers imposed by the resistant plant. Other forms of resistance are less specific. The nature of resistance to most diseases and nematodes is, for the most part, unknown.

Numerous genes for resistance to the rust and leaf blight diseases in corn and to smut diseases in grain sorghum have been identified. The genetic nature of resistance to other diseases remains to be determined. Little work has been done on the inheritance of virulence and the genetic variability in the pathogens of these two crops.

Limited work has been done on applied breeding for disease resistance in corn and grain sorghum. Commercial plant breeding firms are poorly staffed and equipped to do sophisticated research on disease resistance. Applied breeding efforts are presently largely empirical and often inefficient.

OBJECTIVE: To identify and evaluate the relative effectiveness of various sources of resistance to disease, study the genetics and physiology of host-pathogen interactions, determine the most efficient breeding procedures, and transfer superior forms of disease resistance to plant types that can be used to produce productive well-adapted hybrids.

RESEARCH APPROACHES:

A. Observe available germ plasm, including exotic varieties and wild relatives, for reaction to specific pathogens, viruses, and nematodes with particular emphasis on those associated with the root and stalk rot diseases.

B. Determine the nature of each form of disease resistance and its usefulness in disease control.

C. Determine the identity, number, and the action of genes conditioning each form of resistance.

D. Study the variability and genetics of the various pathogens, viruses, and nematodes with particular emphasis on pathogenicity.

E. Develop appropriate genetic stocks for maintaining genes for resistance and for use in studies on the biochemistry of disease resistance and the genetic nature of host-pathogen interactions.

F. Determine the relative efficiency of various breeding procedures for (a) development of source populations, and (b) for transferring disease resistance to an established inbred line.

G. Develop disease resistant synthetics and other source populations from which superior inbred lines may be isolated.

H. Coordinate with research in RPA's 207-B, 307-B, and 307-C.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Production costs and hazards will be reduced, grain yields increased, and quality improved. Diseases cause an estimated national loss of 15 percent of the grain crop in corn and 11 percent of the grain crop of grain sorghum. In epiphytotic years losses are much heavier. A major portion of these losses might be saved through the use of resistant hybrids. Control of stalk rot alone could result in a 10 percent increase in corn yields in the main corn producing areas of the U.S. Based upon production and price for the years 1960-66, this annual loss would be in excess of $85,000,000 for only one of these states (Illinois). Since losses in grain yield due to disease occur after a major portion of the seed, land, fertilizer, insecticide, herbicide, and labor costs have been invested, satisfactory disease control should substantially decrease production costs for each unit of grain.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
15	21

TITLE: Control of disease through the use of pesticides and management practices. RPA 208-C.

SITUATION: Corn and grain sorghum hybrids resistant to all diseases are not available and are not likely to become available in the immediate future. Adequate resistance may not be possible for certain diseases. Therefore, investigations to develop alternative control measures are needed. Many seed- and soil-borne diseases can be controlled through the use of fungicide seed treatments. Chemicals should be tested and superior products identified. Populations of insect vectors of viruses and other pathogens and populations of nematodes (both as primary pathogens and as vectors of other disease agents) can be reduced through the use of insecticides and nematocides. Recent developments in the control of leaf diseases of cereal crops with low volume spraying of fungicides suggest that control of foliage diseases of corn and grain sorghum by this means may be feasible. New systemic fungicides are effective against smut diseases of wheat and barley and should be tested on corn and grain sorghum. Losses due to nematodes and root and stalk rots of these crops may be reduced through the application of suitable management practices. It may also be possible by this means to keep to a minimum the injurious effects of toxic residues in the soil. These residues are derived from impurities and break-down products of herbicides, insecticides, commercial fertilizers; and other chemicals.

OBJECTIVE: To study and develop effective means for the control of corn and grain sorghum diseases through the use of pesticides and management practices.

RESEARCH APPROACHES:

A. Study the effectiveness of various types and rates of chemical seed treatments for use in the control of seed-and soil-borne diseases, determine superior materials and methods of application.

B. Study the effectiveness of various insecticides and nematocides for use in the control of insect vectors and of nematodes, and determine superior materials and methods of usage.

C. Test chemical agents for systemic or localized control of foliage, root, and other diseases and develop techniques for the effective use of such agents.

D. Study hyperparasitism as a method for control of phytopathogenic fungi, bacteria and nematodes, with particular emphasis on those associated with the root and stalk rot diseases.

E. Develop effective management practices including fertilizer application, nutrient balance, irrigation, pesticide application and others that are compatible with sound crop production methods and also effective in reducing or preventing losses due to root rot, stalk rot, and other diseases.

F. Study the phytotoxicity, compatibility with other pesticides, and residues of chemical seed treatments and vector control insecticides and nematocides.

G. Coordinate with research in RPA's 207-C, 207-E, 209-A, 209-F, 307-E, 308-A, and 309-A.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Production hazards will be reduced, grain yields increased, and quality improved. Benefits from total disease control are quantified and given for 208-B. Approximately four per cent of the corn disease losses and three percent of the grain sorghum losses due to diseases are of the type that might be saved by the application of pesticides and development of proper management practices.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
7	10

TITLE: Storage diseases and relationship of disease to quality. RPA 208-D.

SITUATION: Corn and grain sorghum grain is frequently harvested and stored at moisture levels that permit molds, bacteria, and insects to flourish. Improper storage of silage also favors spoilage. When stover and grain is left standing in the field and harvest delayed for winter feeding of livestock, the plant becomes covered with fungal growth. These microorganisms reduce feeding quality and frequently introduce toxic by-products harmful to man and livestock into the substrate. Corn infected by Gibberella spp. is particularly toxic to swine. Grain types with modified proteins high in lysine appear to be more susceptible to ear and kernel diseases. This could be of considerable importance in relation to world food needs. Of even greater importance is that toxins carcinogenic to man and animals are produced by species of Aspergillus and Penicillium growing on corn and sorghum grain.

OBJECTIVE: To study the effect of moisture content, storage conditions, and grain endosperm types on storage and kernel-rot diseases, the effect of weather and other factors on spoilage of stover, grain, and silage, the effects of these and other diseases on quality, and to develop means of preventing losses.

RESEARCH APPROACHES:

A. Identify the various molds and bacteria including identification of toxic products developing on grain, stover, and silage and determine their effects on feeding, processing and seed quality.

B. Determine the relationship of endosperm type to ear- and kernel-rot susceptibility.

C. Determine the conditions favorable for mold and bacterial growth, production of their toxic by-products, and develop means of preventing the growth of these organisms.

D. Coordinate with research in RPA;s 308-B, 405, 408-A, 408-B, and 504-A.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Reduced loss of livestock production from consumption of low quality or toxic feed, prevention of injurious effects on man, and increased seed quality would occur. The magnitude of potential benefits is difficult to quantify because the value of human health cannot be expressed in monetary units. In terms of animal and crop production, however, benefits would involve millions of dollars annually.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
4	8

TITLE: Identification, etiology and control of foreign diseases with potential for damage in the U.S. RPA 208-E.

SITUATION: Several pathogens causing important diseases of corn and grain sorghum in other parts of the world are not known to occur in the U.S. Examples are downy mildews of corn and sorghum in Asia and Africa, bacterial and fungal stalk rots of corn in India and the U.A.R., and virus diseases of corn in Europe. There are many others. The danger of introducing new pathogens is continually present. Furthermore, pathogens are generally most destructive when recently introduced into new areas. Although some work utilizing PL 480 funds is underway, the reaction of major U.S. corn and grain sorghum hybrids and other germ plasm to many of these pathogens occurring in other parts of the world is not known. Control practices applicable in foreign countries may not be effective in the U.S. Where feasible, PL 480 funds should be used to support this research.

OBJECTIVE: To identify diseases of corn and grain sorghum that do not occur in the U.S., determine the area in the U.S. where they might flourish and the potential damage that might result if the pathogens were introduced, and determine the reaction of U.S. germ plasm to foreign disease organisms and the applicability of other control measures.

RESEARCH APPROACHES:

A. Identify foreign diseases of potential importance.

B. Study nature of disease and its causal agent in areas where it is a problem.

C. Evaluate U.S. inbreds and hybrids for reaction to pathogens, viruses and nematodes in areas where the diseases are found. An alternative would be the establishment of a suitable isolation facility where field plantings of corn and grain sorghum and disease tests could be made.

D. Where feasible, PL 480 funds would be used to develop resistant lines adapted to U.S. areas where disease would most likely be a problem if introduced.

E. Examine foreign control measures for their applicability to U.S. conditions.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Minimize adverse effects upon U.S. corn and grain sorghum production if foreign pathogens are introduced. It is not possible to quantify the benefits of protection against new diseases because it is difficult to predict the magnitude of losses caused by foreign pathogens under U.S. conditions. However, with major crops such as corn and grain sorghum, a loss of only one percent would amount to many million of dollars per year.

RESEARCH EFFORT:	T F RECOMMENDATION	
	1972	1977
	3	5

RPA 209 -- Control of Weeds

INTRODUCTION

Both annual and perennial species of weed grasses, broadleaf weeds, and sedges infest the fields in which corn and grain sorghum are produced. Much of our whole system of producing corn and grain sorghum (seedbed preparation, row width, rotations, fertilization, etc.) has been greatly influenced and restricted by the necessity of providing for weed control. These weeds reduce yields, reduce quality, increase the cost of production and harvesting of both crops, harbor insects, and are alternate hosts for major diseases and nematodes that infect corn and grain sorghum. Estimates from Losses in Agriculture indicate that weeds reduce yields of corn by 10 percent of the potential yield; and by 13 percent for grain sorghum.

TITLE: Develop combinations of practices for weed control. RPA 209-A.

SITUATION: Although effective control treatments have been developed for weeds such as crabgrass and pigweed in some regions, no one treatment will control all problem weeds in either crop in any region. Treatments that are highly effective in one area will fail completely in another region of different climatic characteristics, or of a different soil type. Our best chances for effective, practical control of the weeds in each crop are in the development of combinations involving two or more components such as cultural practices, biological control, crop rotations, and herbicides. Currently, our most effective combinations of treatments for control of weeds in corn or grain sorghum include components as follows: (1) good seedbed preparation and one or two postemergence cultivations (approximate cost -- $3.00/A); (2) a banded or broadcast application of a herbicide at planting (approximate cost -- $5.50/A); and (3) one postemergence, broadcast application of a herbicide (approximate cost -- $1.95/A). The combined cost of using all these components approximates $10.45/A, but very few farmers use more than two of these components. Research is being conducted to improve the efficiency of treatments within different combinations, and to develop combinations that are better than the ones we now have. Success in this research with combinations for each crop within each region would enhance our ability to combine different treatments into systems of weed control aimed at specific weed complexes growing under each of the different environmental conditions that are involved in producing these crops.

OBJECTIVE: To develop information that will facilitate the combining of individual weed control treatments and other cultural practices into practical systems of crop production that will provide effective control of all major weeds within each geographic region where the crops are produced. Specifically, our goal is to reduce losses because of weeds to no more than 3 percent of the potential yield of corn, and to no more than 4 percent of the yield of grain sorghum; and to reduce current costs of control by $1/A for each crop.

RESEARCH APPROACHES:

A. Investigate the possibility of eradicating major weeds such as shattercane, witchweed, johnsongrass, and nutsedge through treatments applied to crops grown in rotation with corn or grain sorghum.

B. Study different combinations of treatments applied in corn or grain sorghum for efficacy against specific complexes of weeds common within each region.

C. Investigate the ecological effects of different combinations of cropping sequences, herbicide rotations, cultural practices, and biological control on the natural weed infestations.

D. Study combinations containing at least one component that works well under each of the normally encountered extremes of weather conditions.

E. Use the results of research in RPA's 207-C, -D, 208-C, 209-B, -C, -D, -E, -F, -G, 307-E, and 309 to improve the effectiveness of individual treatments involved in systems of weed control.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Losses in yield and quality, and costs of production will be reduced. Reasonably successful efforts in RPA 209-A would reduce annual losses by 7 percent of the potential for corn; and by 9 percent for grain sorghum. Reductions in cost of weed control would approximate a total of $72 million for both crops. Benefits of RPA's 209-B through -F would be largely realized through contributions to RPA 209-A; we estimate that 15 percent of the total benefits described above should be credited directly to RPA 209-A.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
4	6

TITLE: Evaluate new herbicides and improve the safety and effectiveness of current materials. RPA 209-B.

SITUATION: A number of herbicide treatments effectively control many of the problem weeds of corn and grain sorghum in combination with other practices. However, most of the herbicides have serious limitations in use because of drift hazards to adjacent sensitive crops (2,4-D and dicamba), persistence in soil at levels toxic to succeeding crops (atrazine, propazine, and linuron), and damage to corn or grain sorghum (2,4-D to both crops and atrazine to grain sorghum). There is need for additional information on how herbicides move from the point of application, and on their persistence in soil, water, and plants. The best available herbicides and combination treatments are only marginally effective against a number of weeds which are intensifying as problems in the regions where they occur. The most important of these weeds are giant foxtail, johnsongrass, quackgrass, Canada thistle, shattercane, nutsedge, sandbur, Texas panicum, and woollyleaf bursage. Volunteer crop plants can also become serious weeds.

OBJECTIVE: To obtain information on how new herbicides, new formulations, mixtures, and improved uses of older materials can be used to obtain better control of weeds and reduce problems and hazards now being encountered.

RESEARCH APPROACHES:

A. Evaluate new herbicides, now formulations, combinations, and new methods of applying older herbicides for selective herbicidal action against major problem weeds of each production region.

B. Determine minimal quantities of herbicides which may be applied without loss of effectiveness by using mixtures of herbicides, adjuvants, and new application techniques to reduce costs and soil persistence.

C. Investigate herbicide measures for control of major problem weeds during periods of land fallow.

D. Investigate those factors which influence penetration, absorption, and translocation of herbicides in plants to improve activity and selectivity.

E. Conduct research to characterize the persistence and movement of herbicides in soil, water, and plants.

F. Conduct research to develop methods of controlling the movement and persistence of herbicides in soil, and of controlling movement from the target area.

G. Coordinate with research of RPA's 209-A, -C, -D, and 307-E.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Success in this research area would increase yields and improve quality of corn and grain sorghum, ensure maximum land utilization by methods which are safe for rotational crops, and reduce costs of production. Benefits from 209-B would be realized in 209-A, and would contribute approximately 20 percent of the total benefits from 209-A.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
5	8

TITLE: Mechanism of herbicide action. RPA 209-C.

SITUATION: The site of action and associated physiology of seven of the herbicides used in corn and grain sorghum are known in general principle. The basis for tolerance by the crops is known for four. Herbicides used for both corn and grain sorghum are detoxified in the two crops by totally different mechanisms. Extension of the established principles to include problem weeds (primary targets for research) has been conducted only to a limited extent. The mechanisms of lethal action and of selective toxicity of the numerous other recommended herbicides remain to be established. Most herbicides occasionally fail to produce desired weed control or occasionally damage crops. Better understanding of the principles of herbicide action as altered by environment and physiology in the specific weeds should lead to improved practices; and should be useful in the search for better herbicides. The seven chemicals whose actions are now known act at a single biochemical site which is common to plants, but is absent in animals. Some herbicides not now used extensively in corn or grain sorghum act through multiple inhibitions; when one mechanism fails to control weeds the second mechanism can still kill the plant. Complete knowledge of mechanism of action would reveal potential health hazards if they exist.

OBJECTIVE: To determine the mode of action and basis of selective toxicity of herbicides as related to the life history, biochemical processes, and responses to environment of the crops and specific weeds; and to relate this information to the efficacy of herbicide usage.

RESEARCH APPROACHES:

A. Determine the effects of herbicides on various metabolic systems in major weeds and crop plants; determine the secondary effects of these actions including build-up of natural products (which may be either toxic or highly nutritious to man and other animals, or associated with resistance of the treated plant to herbicides); determine physiological and biochemical differences between weed and crop species and differences at different stages of development of a single species as related to response to herbicides.

B. Study the influence of environmental factors on the response of major weeds and both crops to herbicides.

C. Develop and test theories based on results of 1 and 2 above to explain herbicide action and selectivity, unexpected crop damage, weed control failure, and timing of applications for greatest weed susceptibility.

D. Coordinate with research of RPA;s 209-A, -B, -E, and 307-E.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: More efficient control of weeds, less injury to crops by control treatments, and reduced problems with respect to pesticide residues in food and feed products would result. These benefits would be realized through RPA 209-A, and should approximate 20 percent of the total potential benefits of RPA 209-A.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
8	10

TITLE: Development of design and operational specifications of equipment for herbicide applications and other systems of weed control. RPA 209-D.

SITUATION: Hydraulic sprayers and granular application equipment are being used to apply most of the herbicides that are used to control weeds in corn and grain sorghum. The equipment used is adequate when properly calibrated and operated under ideal conditions, but inadequate control frequently results because of inaccuracies in the rate of application, lack of precision in placement, and lack of uniformity in distribution on plants and soil. Also, the use of tools such as plows, harrows, planters, and cultivators aid in controlling weeds. These tools generally do an adequate job if they are properly adjusted and used at the right stage of weed growth when soil and climatic conditions are favorable. Applying herbicides and flame to emerged weeds in corn and grain sorghum frequently fails to control the weeds, and may damage the crops. Available equipment does not provide an adequate means of contolling placement and retention of the heat or chemical on the weeds and minimizing contact with the crop. Equipment and techniques for incorporating and injecting herbicides into the soil have been developed and are moderately successful under some conditions. It is difficult to control the rate of application, obtain precise placement, obtain uniform coverage, or prevent drift when aircraft are used to apply herbicides. Maintaining constant field speed with herbicide application equipment (either ground or air) is mandatory if correct application rates are to be maintained. Available equipment does not have adequate control of ground speed or control of the discharge rate so that it could be varied with speed. A major problem in the development of new and/or improved equipment and methods of weed control in corn and grain sorghum is the lack of specific information on the performance requirements. Knowledge of the influence of soil, climatic, crop growth, and weed growth conditions on the performance of weed control equipment and methods is essential to development of design and operational specifications for the equipment.

OBJECTIVE: To develop design- and operational-performance requirements for equipment used in applying herbicides and in other weed control systems.

RESEARCH APPROACHES:

A. Analyze and use data on movement of specific herbicides in soil, and on the mode of phytotoxic action in the development of design criteria for herbicide application equipment.

B. Utilize basic data on the requirements of weeds and crops for nutrients, water, and aeration in the development of design and operational specifications of tillage equipment.

C. Investigate the use of automatic guidance systems (such as electric-eye equipment) for potential in directing sprays or granules, and for spot-application of herbicides to tall weeds.

D. Investigate curtains of air, water, or gas to control placement of herbicides or flame after emission from the applicator.

E. Study methods of applying herbicides as foam, gels, or particulates.

F. Investigate the possibility of developing an accurate metering and distributing device that would discharge herbicides by a rate directly proportional to speed.

G. Investigate the possibility of developing a speed control device so that constant ground speeds can be maintained regardless of terrain.

H. Explore new methods for maintaining spray nozzles and granule applicators in a desired position in relation to the soil and to the crop.

I. Study methods of eliminating ultra-small droplets from spray nozzle applications as a means of reducing drift from the target area.

J. Coordinate with research of RPA's 207-C, -D, -E, 208-C, 209-A, -B, -F, -G, 307-E, 308-A, and 309; and with engineering research on weed control equipment for other commodities.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: The realization of benefits described in RPA 209-A would be expedited through improved efficiency of herbicide usage and better nonchemical methods of weed control, and losses due to phytotoxic residues and drift of herbicides would be reduced. Potential benefits would approximate 15 percent of the total listed in RPA 209-A.

RESEARCH EFFORT:	T F RECOMMENDATION	
	1972	1977
	3	3

TITLE: Comparative biology, physiology, and ecology of corn, grain sorghum, and specific weeds. RPA 209-E.

SITUATION: A diverse group of annual and perennial weed species, many of which cannot be adequately controlled by present herbicides, commonly infest corn and grain sorghum. Generally, little is known about the elements of their biology, physiology, and ecology which could provide a basis for the exploitation of any inherent weakness by mechanical, chemical, or biological control procedures, or to take increased advantage of superior characteristics of improved varieties of corn and grain sorghum. With fundamental knowledge on their competitive characteristics, their requirements for germination, establishement, growth, and reproduction, considerable gains can be made toward better control procedures, and in reducing levels of infestation.

OBJECTIVE: To determine and exploit differences in the biology, physiology, and ecology of problem weeds in corn and grain sorghum as a means of improving current control procedures and reducing future infestations.

RESEARCH APPROACHES:

A. Determine which weeds compete most with the crop and identify the stage of crop growth at which competition is most harmful.

B. Determine what can be done to increase the competitive ability of the crop plants through selection of varieties and improvement of cultural practices.

C. Determine the requirements for the germination, growth, establishment, and reproduction of problem weeds and how these can be exploited to provide better methods of control.

D. Determine the physiological basis for superior growth of weeds or crops with respect to utilization of nutrients, water, light, and release of inhibitory substances by plants.

E. Coordinate with research of RPA;s 209-A, -C, -F, 307-A, and 307-E.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Increased returns per unit of investment through better yields and reduced weed infestations, and possible reductions in requirements for using herbicides would result. These benefits should contribute at least 20 percent of the total benefits to be realized through RPA 209-A.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
9	10

TITLE: Control of weeds by means other than herbicides. RPA 209-F.

SITUATION: Nonchemical weed control, through the use of mechanical implements, continues to be an important adjunct to chemical methods of control in corn and grain sorghum. Improvements in mechanical methods could be made in respect to both equipment design and operation, and timing in conjunction with crop and weed growth. Currently, a lack of adequate herbicides for specific weeds, such as shattercane, and johnsongrass in grain sorghum, emphasizes the importance of developing nonchemical methods. Inadequate attention has been focused on the nonchemical approaches such as flaming and the use of other forms of physical energy. There has been very little research on possible use of biological control agents, such as diseases and insects, for control of weeds in corn and grain sorghum.

OBJECTIVE: To determine the means of utilization and efficacy of various forms of mechanical implements, heat, electricity, light, sound, and biological agents for the control of specific weeds in corn and grain sorghum.

RESEARCH APPROACHES:

A. Determine if mechanical methods of control, by existing or newly designed machinery, can be satisfactorily employed during crop and fallow seasons.

B. Study the effects of heat, electricity, light, and high-frequency sound on weeds and crops at different stages during their development.

C. Evaluate the use of insects and plant disease organisms for control of specific weeds that are resistant to current methods of control (including domestic organisms, and foreign insects and diseases through PL 480 research).

D. Evaluate the use of poultry and small animals for usefulness in controlling specific weeds that are resistant to current methods of control.

E. Coordinate with research of RPA's 208-C, 209-A, -D, -E, -G, 307-E, 308-A.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Decreased production costs, decreased yield losses due to weeds, and decreased problems associated with the use of herbicides should result. Approximately 15 percent of the total benefits expressed in RPA 209-A would accrue from RPA 209-F.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
3	4

TITLE: Techniques for repelling and excluding birds, rabbits, deer, and other wildlife. RPA 209-G.

SITUATION: Birds and small rodents often damage, and sometimes destroy, plantings of corn and grain sorghum by eating the seeds or young seedlings. Deer, raccoons, birds, and other animals damage corn and grain sorghum at all stages of crop growth. Birds frequently cause extensive damage, in some locations, by eating and shattering seed of mature grain sorghum just before harvest. Ordinary fencing, electrical fencing, noise-making devices, scarecrows, recordings of bird distress calls, predator scents and other chemical repellents, trapping, dynamiting of roosts, poisoning, and shooting may be used to repel, exclude, or kill birds and other wildlife. Methods which destroy the offending wildlife are highly objectionable for obvious reasons. The other methods are generally either low in effectiveness, expensive, or poorly adapted for use in large fields. Although we know that birds and other wildlife cause significant losses in both corn and grain sorghum, we are currently unable to quantify these losses. We also know that wildlife, particularly birds, are beneficial in some respects, as for example, biological control of insects and weeds.

OBJECTIVE: To identify, characterize, and mitigate losses caused by birds and other wildlife without killing or injuring the offenders.

RESEARCH APPROACHES:

A. Identify the exact species of wildlife involved in specific situations, and measure the benefits and losses they cause in these situations.

B. Investigate different types of flashing lights, recorded sounds, moving mechanical men and predatory animals, and other nonchemical techniques as repellants.

C. Study different designs of common and electrified fencing for improved efficiency in excluding specific species of wildlife.

D. Develop economical repelling chemicals.

E. Investigate the potential of planting alternate "free-lunch" crops for offending wildlife in areas adjacent to crops.

F. Characterize the economics of public reimbursement of individuals sustaining severe losses in locations adjoining wildlife refuges.

G. Investigate the potentials of breeding corn and grain sorghum for resistance to damage from wildlife.

H. Investigate the potential of using controlled sterilization to reduce population of rampant species such as blackbirds.

I. Coordinate with research of 209-A, -D, -E, -F, 307-E, 308-A, and 309.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Losses in stands and yields would be reduced. Although we have little data for quantitating the losses, crop scientists and wildlife specialists estimate that current losses in corn and grain sorghum average approximately 1 percent of the potential yields, but that losses in localized areas are much hgiher (losses of 15 to 50 percent are not uncommon). We could logically expect to reduce these losses by 50 percent.

RESEARCH EFFORT:	T F RECOMMENDATION	
	1972	1977
	1	1

RPA 307 -- Improvement of Biological Efficiency

INTRODUCTION

During the past quarter century, striking yields increases have been achieved in both corn and sorghum. Progress attained to date has come about as a result of a combination of factors including the development and use of improved hybrid varieties, the adoption of improved cultural practices and the greatly increased use of essential plant nutrients, especially nitrogen.

Comparable progress in the future requires improvements or "breakthroughs" in basic knowledge of physiology or biochemistry upon which applied technology can be based. For example, current methods of plant breeding have changed little since the introduction of hybrid corn, and are based largely on exploitation of the hybrid vigor exhibited by first generation crosses. Yet the genetic basis for hybrid vigor and the physiological-biochemical processes associated with the heterotic response are largely unknown quantities. Further significant progress is dependent upon the development of more efficient breeding methods. The assessment of enzymes may offer the best approach to improved breeding efficiency. Since enzymes are the nearly direct product of the genes and as the amount and kinds of enzymes present in the cells dictates the kind of metabolism and metabolism in turn determines the nature of the whole plant, measurements of the amount and kind of enzymes present permits an assessment of the genes and genotype and the nature of metabolism. This kind of information will serve as a guideline for knowledgeable breeding of varieties with specified metabolic composition meeting the required criteria, e.g. greater yield, higher protein, or resistance to disease and insects, etc.

Although the total volume of mineral nutrients used on corn and sorghum acreage has multiplied many times since World War I, adequate knowledge is still lacking of the mineral nutrient requirements of these crops, especially when grown at high levels of production. Moreover, we are only beginning to develop an understanding of the micro element requirements of these species.

Corn and sorghum plant types are what they are today because of selection in specific directions, and not because they are necessarily the most efficient plant types available. Corn and sorghum encompass tremendous genetic variability and are highly plastic species. Attempts should be made to use this variability to develop varieties which are most efficient with respect to nutrient water and light utilization irrespective of plant type.

TITLE: Investigation of methods and procedures involved in the application of physiological, molecular and quantitative genetics to breeding. RPA-307-A.

SITUATION: The success of hybrid corn is frequently cited as the outstanding example of the application of genetic principles to plant improvement. Breeders have made remarkable progress in improving both corn and sorghum. Yet, the methods by which success has been achieved have been largely empirical. With the use of current methodology, breeders are finding it increasingly difficult to make further significant improvement in productivity. Few attempts have been made to apply recent findings in physiological, molecular and population genetics to selection schemes designed to further improve corn and sorghum. Research has barely begun on the nature of biosynthetic pathways in plants, yet the many mutant strains of maize and sorghum provide excellent experimental tools for the biochemist and molecular geneticist.

OBJECTIVE: To develop a clearer understanding of the fundamental biosynthetic pathways in plant development, to relate these to plant productivity, and to determine the genetic bases for the biochemical and physiological processes involved. To develop and test methods of best applying the principles of quantitative genetics to selection.

RESEARCH APPROACHES:

A. Determine the basic biochemical and physiological processes involved in starch, oil and protein synthesis and subsequent deposition in the grain.

B. Investigate mode of inheritance and gene action sequence involved in carbohydrate, oil and protein biosynthesis.

C. Investigate the influence of protein and oil content on yield and other characters.

D. Investigate relative efficiency of different breeding systems with respect to yield and other economic traits.

E. Investigate the role of population size in selection.

F. Coordinate with research in 307-F, 307-G and 307-H.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: A better understanding of the relationship between genotype and metabolism is basic to the development of more efficient breeding methodology. Ultimate benefits should accrue in the form of improved genetic potential for yield, improved nutritive value and more efficient utilization of nutrients, water and light.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
42	45

TITLE: Genetic and cytogenetic studies on control of biological processes. RPA 307-B.

SITUATION: Despite a vast store of knowledge on the phenotypic expression of numerous genes of corn and sorghum, little is known of the precise mechanism of gene operation. Little effort is being made currently to correlate information on chromosome knob patterns and distribution with the evolutionary pathways of corn, all of which is probably associated with heterotic response in crosses.

Information on gene action at the biochemical and molecular levels has been derived largely from work with the lower organisms (bacteria, fungi, etc.). Similar studies with higher plants of economic importance are needed if we are to understand the mechanisms of gene operation controlling important economic traits.

OBJECTIVE: To develop through genetic and cytogenetic studies a better understanding of gene function and to develop procedures to apply this information to practical breeding and plant improvement. To relate pertinent cytological information to breeding behavior.

RESEARCH APPROACHES:

A. Investigate the mode of gene action with special emphasis on economic characters in corn and grain sorghum.

B. Investigate the use of chromosome morphology as a tool in studying the evolutionary pathways in corn and its relatives.

C. Determine the relationship between chromosome knob patterns and breeding behavior.

D. Investigate the role of chromosomal structural rearrangements on synapsis and segregation.

E. Coordinate with research in 307-A, 307-F and 405.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Improved genetic potential for yield and other traits of economic importance.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
19	21

TITLE: Identification, inheritance and utilization of resistance to insect and disease pests. RPA 307-C.

SITUATION: Diseases and insects cause an estimated loss of more than one billion dollars per year. As cropping practices become more intensified with increased use of fertilizers and pesticides and with the trend toward increased stand density, disease and insect problems become more acute. Public alarm over the widespread use of pesticides and the demonstrated ability of diseases and insects to adjust to altered environments suggests the need for increased emphasis on genetic resistance.

OBJECTIVE: To identify sources of resistance to important pathogens and insects; to determine, where possible, the nature of resistance; to determine the mode of inheritance of resistance.

RESEARCH APPROACHES:

A. Screen available germ plasm, including world collections, for reaction to the more destructive pathogens and insects.

B. Attempt to identify the nature of resistance.

C. Determine the mode of inheritance of resistance.

D. Coordinate with 207-B, 207-C, and 208-B.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: An understanding of the nature and inheritance of resistance to major insects and pathogens will simplify the problem of breeding, and could possibly result in an average annual reduction of losses of approximately one-half billion dollars.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
24	26

TITLE: Collection and maintenance of germ plasm. RPA 307-D.

SITUATION: Concentrated and continued effort over the past two decades has resulted in extensive world collections of corn and sorghum germ plasm from a wide geographical area. For corn, reasonably complete collections have been made throughout the New World. Supplementing these are a significant number of collections from Europe, Asia and Africa. Extensive collections of sorghum have been made in Africa and India. The important task today is that of maintaining the germ plasm now in storage and supplementing it with collections from geographic areas which have not been adequately covered.

OBJECTIVE: To supplement and maintain the world collections of corn and sorghum through the provision of adequate facilities and personnel; to maintain an efficient system of distribution of germ plasm to qualified breeders and investigators.

RESEARCH APPROACHES:

A. Collection of germ plasm not now in world collections.

B. Investigate new methods of seed storage designed to maintain viability over long periods of time.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: The provision of a continuing source of diverse germ plasm which represents the product of thousands of years of evolution under domestication and which is one of our more important natural resources would result. The loss of any substantial part of these collections would greatly restrict the opportunities for future improvement and also increase the difficulties of coping with new disease and insect pests.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
7	8

TITLE: Development of fertilizer and cultural practices that will maximize production and minimize environmental pollution. RPA 307-E.

SITUATION: Because it has been profitable, farm operators have been applying more fertilizers each successive year for the past two decades. For example, current applications range from 100 to 250 lbs. N per acre and indications are that even higher amounts will be used in the future. Yet the mineral requirements, (amounts, time of application, and balance between macro- and micro-elements) in relation to current cultural practices (new varieties, high plant populations, irrigation, herbicides, improved farm machinery, and changes in the number of crops involved in rotation as mono-crop culture is commonplace) are not well understood. Also, the most efficient combination of cultural methods and cropping practices often are not used. Since many of these newer operations are expensive, especially fertilizers, basic information is needed to insure the most economical usage. Some information is accumulating suggesting that fertilizer elements, especially nitrogen and phosphorus, are being washed or leeched from the soil and contaminating wells, rivers, and lakes.

OBJECTIVE: To develop basic information concerning fertilizer requirements and usages in relation to current cultural practices, and to evaluate combinations of cultural practices, that will maximize production, minimize environmental pollution, and be most economical.

RESEARCH APPROACHES:

A. Determine nutrient requirements, including micro-nutrients, as affected by various cultural practices, especially rate, time, and placement of fertilizers.

B. Evaluate cultural methods and cropping practices to provide elements of information needed for systems analysis (RPA 309) to determine the most economical production practices.

C. Identify and propagate those varieties that are most efficient in absorption, transport, and utilization of nutrients.

D. Investigate and determine what practices provide maximum production with minimum levels of fertilizers, with the ultimate goal of economic production and minimum environmental pollution.

E. Coordinate research with RPA 209, 307-A, 307-F, and 308-A.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Improved plant nutrient and cultural practices could result in yield increase of 5 bushels per acre. Reduction in water shed pollution with nitrate and phosphate not only will permit more economical production, but avoid damage to water supplies, recreational, and habitable areas.

RESEARCH EFFORT:	T F RECOMMENDATIONS	
	1972	1977
	24	30

TITLE: Biochemical criteria as guides for plant breeding. RPA 307-F.

SITUATION: One of the major tenets of plant breeding is that the available germ plasm must be as diverse as possible. Much effort has been expended and major emphasis is currently being given to maintain and expand the collection of germ plasm from the far corners of the earth. In contrast almost no attention has been given to biochemical evaluation of the existing germ plasm pool. An examination of the reviews on plant breeding written by recognized authorities reveal that they are aware of this problem. For example one authority in 1951, stated that there was need to develop more precision in breeding programs. Precision was defined as the development of indices that would measure "genetic potential performance rather than actual end-result behavior." These indices were not further defined. This statement is equally valid to date. It is also obvious that genes are not only the underlying basis for physiological advantages, but that they specify the kind and amount of enzymes that constitute the overall metabolism. A measurement of the amount and kind of enzymes of the various genotypes is one way of indirectly assessing and indexing the genes. Such assessment of enzymes also provides insight into the metabolism of the plant. This assessment of enzymes and their relative level of activity throughout the growing season provides a means of obtaining the "Precision in Breeding" requested. Pioneering investigations have established guidelines for investigations of this type. Again the problem lies in the lack of basic information of the gamut of enzymes that constitute the whole of metabolism. It is obvious that this is a complex problem because of the multitude of metabolic interactions (level and efficiency of enzymes that constitute the assembly line of metabolism) involving the various genotypes and environment. It is equally clear that work of this type must be carried out with crop plants that provide the world's food supply rather than with obscure plant species.

OBJECTIVE: To provide biochemical criteria useful to the plant breeders as a guide in development of superior crop varieties.

RESEARCH APPROACHES:

A. Determine the relative level of numerous enzymes that are considered key or rate limiting steps in various metabolic pathways (e.g. nitrate reductase in the reduction of inorganic nitrate) in a large number of inbred lines that are commonly used in commercial hybrids.

B. Determine the mode of inheritance of the enzyme in the hybrids.

C. Determine the relative level of the enzyme in the various hybrids from seedling stage to maturity, to determine the relationship of this seasonal activity to final product (for nitrate reductase the product would be protein in vegetation and grain).

D. Other enzymes or enzyme systems that are prime prospects are: ribulose diphosphate or pyruvic kinase carboxylase -- enzymes that fix CO_2; glutamic dehydrogenase the key enzyme in de novo synthesis of

amino acids; the ability of cholorplasts to convert light energy into chemical energy; acetoacetyl CoA thiolase the enzyme that initiates fatty acid synthesis; triosephosphate dehydrogenase the enzyme that reduces CO_2 etc.

E. Determine if evaluation of enzyme levels in seedlings can be used as a basis of selection of superior varieties.

F. Coordinate research with 207-B, -D, 208-B, -A, -D, -E, 209-A, -C, -E, 307-A, -B, -C, -D.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Research on physiology (biochemistry, and metabolism) provides the essential elements of information needed for improvement in breeding, response to fertilizers, resistance to disease and insects and tolerance to environmental stress. This becomes obvious upon reading the major RPA cited herein and proposed coordination of research. Benefits will be derived in development of varieties with greater yield potential, savings in time required to develop such varieties and more efficient use of fertilizers and herbicides.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
13	27

TITLE: Light interception as affected by leaf canopy structure and their relationship to grain production. RPA 307-G.

SITUATION: Light is the energy source for all growth and production processes of the plant. Therefore, it would seem that maximum yields would be obtained through management that would maximize total leaf surface per acre over the greatest number of days of the growing season thus permitting the capture of the highest amount of available radiant energy. While this may hold for forage crops, the production of maximum vegetative cover is not necessarily correlated with maximum grain production. Thus a wide-leafed early developing variety could completely cover the ground very early and look like a "top yielder" at that stage. However, the heavy top cover could completely shade the bottom leaves leading to their early senescence. This in turn could deprive the roots of needed nutrition causing them to be inoperative at the crucial time of grain initiation and development. The problem is complicated by the interaction of: (a) leaf width; (b) leaf angle; (c) growth rates during different stages of plant development and maturation; (d) the physiological efficiency of light driven photsynthetic reactions as affected by leaf position (number) at various stages of plant development and number and location of ears (sumps); (e) the capability of the various leaves and their vascular systems to transport the products synthesized to the proper organ at the right time; (f) day length and growing season; (g) plant population. Some of these factors and their interactions have been recognized as illustrated by current practices of: (a) high planting rates (24,000 plants/A vs. 12,000 in 1950); (b) short stature hybrids; (c) erect leaf structure; and (d) row spacing. The problem resides in the fact that not enough basic information is available on the individual factors to permit an overall assessment and solution.

OBJECTIVE: To evaluate individually and integrate such factors as listed above so that all leaves receive the optimum amount of light at the proper stage of development that permits maximum grain production for each individual plant.

RESEARCH APPROACHES:

A. Survey and or utilize the existing germ plasm pools for studies on leaf anatomy and morphology and interaction with plant population.

B. Evaluate the physiological efficiency of various genotypes with respect to the ability of the leaves at various positions and stages of development to (a) fix CO_2 (b) reduce nitrate (c) synthesize protein (d) convert light energy to chemical energy and (e) the efficiency of transport from these leaves to other parts of the plant.

C. Evaluation of growth rates by such indices as leaf area index and net assimilation rates.

D. Investigate the existing single gene mutants that modify plant geometry so that leaf canopy, leaf width, leaf angle, plant height,

and seed bearing structures can be evaluated both individually and in combinations in certain ecosystems. Needed information on the measurements of the effects of these genetic factors on variables of the ecosystem and their interactions should point the way to the plant geometry necessary to maximize grain yields.

E. Coordinate research with 307-A, -F, -I.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: A breakthrough in this area of more efficient conversion of light energy to chemical energy by crop plants would permit the development of superior varieties. Any production increase would be of tremendous impact because of the acreage involved, furthermore, the basic information that might be expected from research approach No. 2 would be applicable to other areas such as horticulture or forestry.

RESEARCH EFFORT:	T F RECOMMENDATION:	
	1972	1977
	10	12

TITLE: Growth regulators. RPA 307-H.

SITUATION: From existing studies it is apparent that metabolism can be affected both favorably and adversely by addition of natural auxin and hormones or chemical compounds that can substitute for natural components. The naïve approach is to state that numerous chemicals should be screened and those that exert favorable effects should be selected and applied. The difficulty is that these compounds are interacting with the natural (three types are known) hormones and the natural hormones are interacting with each other. Since the hormonal levels are dynamic depending on genotype, stage of development and environment, the status of metabolism which is in part regulated by the natural hormones is in a state of flux. For these reasons, application of a given level of the growth regulator may exert a favorable, adverse or no effect depending on the status of the natural hormones and metabolism at that particular time.

OBJECTIVE: To acquire enough knowledge about the levels of natural hormones and growth regulators and their interactions and effects on metabolism so that exogenous compounds can be applied at a time to achieve favorable effects.

RESEARCH APPROACHES:

A. Investigate and develop knowledge concerning the natural hormones with special emphasis on level and interaction of these hormones on metabolism throughout the life of the plant.

B. Continue to screen various chemicals in an attempt to find growth regulators or stimulants that will favor enhanced production.

C. To conduct exhaustive biochemical and physiological studies on chemical compounds that show some promise of favorable effects on yield. These studies would, most likely, be interrelated with comparable studies of the natural hormones.

D. Coordinate research with 307-A, -F, 209-B, -C, -E.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: The development of a single compound that would consistently enhance production would be of great value in view of the acreage and the small cost of the treatment involved. Studies in this area could also add to our knowledge of mode of action of herbicides.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
4	4

TITLE: Improvements in efficiency of water utilization. RPA 307-I.

SITUATION: Water is considered to be a major, if not the first limiting factor in corn and grain sorghum production. Although irrigation circumvents this problem, the demands for irrigation water exceeds the supply. Thus improvements in the efficiency of water use becomes important. It seems most unfortunate that less than 1% of the water absorbed by plant roots is retained within the plant. However, the movement of water into and through the plant aids such functions as movement of solutes into and through the plant, and plant temperature regulation via evaporation (transpiration). Since water is lost from the plant (transpiration) in the gaseous (vapor) form, attempts to reduce this loss by chemicals or films also tends to interfere with plant metabolism or the obligatory uptake of gaseous CO_2, as well as interfere with temperature regulation by the plant. Thus the system involved in efficient water use is complicated and encompasses such additional factors as (a) availability of soil water, (b) root type and distribution, (c) plant and leaf anatomy and canopy, and (d) environemtnal factors of light temperature, relative humidity and wind movement. Only recently has the complexity of this problem been fully realized and the system soil-plant-atmosphere continuum (SPAC) been defined and studied as a whole. Because of the complexity of this system, team research constitutes one of the major, but not exclusive approaches.

OBJECTIVE: To extend the basic knowledge of the individual factors involved in water absorption transport and evaporation from plants and integrate this information into a workable system that will lead to more efficient water use by crop plants.

RESEARCH APPROACHES:

A. Find chemicals or films that will reduce the evaporational loss of water from the plant but not prevent the entry of CO_2 into the leaf.

B. Evaluate the possibility of supplying carbon to the plant in some form other than carbon dioxide (e.g. carbonates).

C. Survey and selection of varieties that exhibit efficient water use characteristics such as extensive root systems, low transpiration rates, metabolism that is resistant to environmental stress, and a final criteria of maximum grain production per unit of water used.

D. Extend the knowledge of plant temperatures and their measurements so that effect of plant temperatures on water loss and metabolism can be effectively gauged.

E. Approach the problem as a whole (soil-plant-atmosphere continuum) which envisages cooperation with RPA 307-A, -E, -F; 209-E, -F.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Development of practices or varieties that permit more efficient water use would increase productivity and efficiency of land utilization.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
10	15

RPA 308 -- Mechanization of production.

INTRODUCTION

Advancing technology in all phases of corn and grain sorghum production, particularly in mechanization, has made it possible to reduce the labor input from 46 hr. per acre in 1880 to 2 hr. per acre for today's better farmers. The successful substitution of mechanization for labor was made possible by substantial increases in the farmers' investment in mechanization. If the efficiency of corn and grain sorghum production is to be further increased, an expanded research program on the development of more efficient methods, techniques, equipment, and structures will have to be undertaken. Research on mechanization of production is concerned with the men, machines, and materials used in the annual production of approximately 4.7 billion bushels of corn and grain sorghum on 72 million acres of land. The potential for fruitful research is indicated by the sizable input of labor and equipment and the need for reducing costs, preserving quality, and avoiding losses. For farmers to receive the greatest benefit, new developments in mechanization need to be evaluated in relation to other technological changes and to their combined effect on the total farm enterprise.

TITLE: Mechanization of production. RPA 308-A.

SITUATION: Equipment and labor comprise a large portion of the inputs for corn and sorghum production. Most equipment was developed as individual units without regard to the total operational requirement. In many instances there is a general lack of compatibility among power units, machine capacities, and operational requirements that is costly to the farmer. Labor inputs in corn and sorghum production have been reduced from 46 hr./A in 1880 to 2 hr./A or less in 1968. It has been estimated that by 1980, 1.0 to 1.3 hr./A will be common. To obtain this high degree of mechanization, it has been necessary to make sizable increases in machinery investment. Using 1910 figures as a base of 100, the machinery investment by farmers increased 450 percent by 1967. Obtaining further substantial reductions in input cost by substituting machines for labor does not appear promising. Reducing machinery inputs both in terms of machinery costs and machine operations offers promise. At the present time the production systems and the equipment used in these systems must provide for seedbed preparation, fertilizer application, planting, weed control, insect control, disease control, irrigation, drainage, erosion control, harvesting and storage. An example of the types of cost reductions that have potential can be found in the recent work on tillage for corn production. Seedbed preparation uses more than one-half the total horsepower hours required to grow corn. It takes 36 to 40 percent of that total power to plow. Research has shown that it is possible to eliminate plowing in corn and sorghum production systems without reducing yields. It should be possible to further reduce tillage operations or develop equipment to perform the necessary tillage with less power. Before this can be done, the soil environment needed for seedling emergence and plant growth must be specifically described so that machines can be designed that will create that environment.

OBJECTIVES: (1) Develop design and operational specifications for equipment for tillage, seedbed preparation, fertilizer application, planting and controlling weeds, insects, and diseases, (2) Develop methods of system analysis and collect input data so that machines and machine operations can be evaluated as part of the total corn and sorghum production system.

RESEARCH APPROACHES:

A. Determine specific requirements for tillage and seedbed preparation so that machine design specifications and machines can be developed.

B. Determine specific requirements for planting and fertilizing so that machine design specifications and machines can be developed.

C. Utilize findings from RPA 207, 208, 209, and 308-B to develop machine design specifications.

D. Gather input data (time, fuel use, labor, etc.) for various field operations along with weather data so that job completion probabilities can be accurately determined.

E. Develop a method of analysis to evaluate machines and machine operations as part of the total corn and sorghum production system.

F. Evaluate experimental and presently available machines and machine operations as part of the total production system.

G. Study the relationships of erosion control, irrigation, and drainage on machinery operations associated with production.

H. This RPA will be closely associated with the following: 209-A, -B, -D, -F, 207-C, -E, -F, 208-C, 307-E, -H. 308-B, 309-A.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: The results of this research should improve equipment, equipment selection, and reduce the cost of corn and sorghum production by 25 to 30 percent.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
7	15

TITLE: Equipment and methods for harvesting, drying and storage. RPA 308-B.

SITUATION: Harvest operations result in field losses of from 10 percent to as high as 30 percent of grain produced in the field. The combine is used to harvest grain sorghum and nearly one-half the corn crop is now harvested directly in the shelled form. However, mechanical damage to as much as 30 percent of the corn kernels has been observed. Rapid harvest required mechanical drying for large volumes of high moisture corn and grain sorghum. During storage, losses occur due to molds, mycotoxins, bacteria, and insects. The effect of all operations on grain quality is of increasing importance.

OBJECTIVE: To improve equipment and methods for harvesting, drying and storing corn and grain sorghum that will result in reduced costs and minimize mechanical damage, quality deterioration, and losses in quantity of grain.

RESEARCH APPROACHES:

A. Improve components of harvesting mechanisms to reduce field losses and mechanical damage, including investigation of squeeze shelling principle for corn.

B. Investigate new methods and equipment for harvesting for specific end uses, including new concepts for harvesting the total corn and grain sorghum plant.

C. Improve equipment and methods for drying large volumes of shelled corn and grain sorghum and determine effects on feed value and mechanical damage.

D. Investigate new techniques for drying grain such as microwave and infrared heating, vacuum drying, alternate heating and cooling, and multiple-stage drying.

E. Determine the deterioration rate of high moisture grain at various temperatures and the relation to mold and mycotoxin development.

F. Explore new techniques for grain storage including hermetic, insulated, and refrigerated storage; controlled environment; and chemicals and inert gases to prevent mold development, chemical breakdown, loss in germination, and insect problems.

G. Determine physical properties of grain related to equipment and procedures for harvesting, drying and handling.

H. Coordinate with research in 208-D, 307-A, -E, and 504-A.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Results of this research should (1) reduce costs and preserve quality and quantity of grain, (2) reduce harvest losses by 3 percent valued at $140 million per year, and (3) reduce drying and storage costs and losses by 2¢ per bushel for corn and grain sorghum stored initially on farms valued at $60 million per year.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
9	12

RPA-309 -- Systems analysis in production.

INTRODUCTION

The benefits of increased production efficiency, that is lower production costs, are abundantly evident in our society. In continuing efforts to lower production costs farmers and researchers ask and require answers to many questions: What would costs be if the best method were used for each production job? Are these best methods mutually compatable? What production jobs offer the greatest potential for research aimed at cost reduction? What new techniques are needed to achieve significantly lowered costs for each job? Are there adjustments in enterprise combinations on farms which would contribute significantly to cost reductions? Would costs be lowered by certain interregional production adjustments?

Because of the wide scope of inquiry, research is necessarily conducted and reported by specialists within each of the several subject fields. Consequently, new techniques developed by research are seldom appraised rigorously in terms of their relationships with other practices in the production system. Choice of variety, method of tillage, time of planting, plant population, row spacing, type of equipment, timing, placement and amount of fertilizer, pest control practices, and end-product use are mutually dependent characteristics of the corn and grain sorghum production system. Systems analysis requires a lucid specification of a system's components and facilitates rational, well-informed evaluation of choices for the several components.

There are a number of approaches to systems analysis in corn and grain sorghum production. In general, a specific approach will entail (1) construction of a model or models to simulate corn and grain sorghum production systems, (2) using the production system model(s) to evaluate extent, emerging, and hypothetical production systems and components under condition assumptions controlled by the investigator, and (3) field testing production systems and components selected by model analysis for validity under actual conditions.

TITLE: Optimizing production systems. RPA 309-A.

SITUATION: Farmers must select from a number of possibilities the crop variety, production practices, materials, and tools, and the operational sequence of their application which contribute optimally to attainment of their objectives. These selections must be mutually compatable and flexible enough to allow for contingencies of weather, insects, disease, and other hazards. More and better data are needed on the variables that may be encountered so that effects on efficiency of adjustments in methods of production, farm organization, and location of production can be measured. As the size of the farming units increases such information becomes even more important.

OBJECTIVE: Develop costs and returns data on production system components which will enable farmers to put together optimal production systems.

RESEARCH APPROACHES:

A. Identify production jobs with greater potential for cost reduction.

B. Identify and analyze alternative ways of doing these jobs.

C. Coordinate with work on RPA 308.

CHARACTERS AND MAGNITUDE OF POTENTIAL BENEFITS: Development of system of mutually compatable production operations yielding optimal contribution to goal attainment.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
1	1

TITLE: Evaluation of Emerging Technology. RPA 309-B.

SITUATION: Continuing research develops new production techniques for consideration as a part of production systems. The number of these innovations and in many cases the sizeable investment associated with them, call for early evaluation in terms of their economic feasibility. Such evaluation would reduce the need for costly trial-and-error appraisal by farmers.

OBJECTIVES: Develop data on physical inputs and outputs and on costs and returns associated with important new technological developments when they first appear. Appraise the effect of selected new techniques on production costs and economic efficiency. Determine the effects of new techniques on the organization and income of farms of different types and sizes.

RESEARCH APPROACHES:

A. Investigate the resource requirements, costs, and yields associated with various production practices such as variety selection, tillage, pest control, plant and row spacing, and harvesting.

B. Evaluate these practices on representative farms to determine the probable impact of their use on the organization, operation, and income of farms.

CHARACTERS AND MAGNITUDE OF POTENTIAL BENEFITS: Production costs will be reduced.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
2	3

TITLE: Farm and regional equilibria. RPA 309-C.

SITUATION: Proper evaluation of economic potential of a farm enterprise requires its consideration as a part of the total farm organization. Enterprise evaluations *per se* are useful for certain purposes, but an enterprise cannot be completely evaluated until it is fitted into a production organization. Certain complementary and supplementary relationships exist between enterprises which have a decided influence on the efficiency with which labor, machinery, capital, and other production resources can be used. Certain enterprise combinations may lead to more efficient use of production resources, and insofar as they do, they lead to hidden economies in the production of specific crops.

In addition, increased efficiency may be attained by effecting adjustments among farms and among regions. In one instance, systems analytic research indicated that the sale and transfer of cotton allotments from less efficient to more efficient farms can result in lower production costs and economic advantage for both seller and buyer. Similar increases in efficiency may be attained by shifting production from one region to another. Such situations, in which everyone benefits by transfer of production from farm to farm or from region to region, may exist for corn and grain sorghum producers. Systems analytic research could discover these situations.

OBJECTIVE: Determine the most efficient combinations of enterprises on farms producing feed grains, especially as they are affected by size of operation and level of technology. Indicate how increased efficiency may be attained by adjustments among farms. Determine potential increases in efficiency by adjustments among areas of production.

RESEARCH APPROACHES:

A. Production coefficients would be derived by production regions for farms of different sizes and with different soil resources and using different levels of technology.

B. Using the above coefficients, systems analytic techniques would be used to determine optimum organizations for maximum profit for individual farm and least cost for regions.

C. Based on the above outputs, opportunities for adjustments among farms and among regions would be analyzed.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Production costs will be reduced and net farm incomes improved.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
3	5

TITLE: Development of types with improved nutritional or industrial use. RPA-405.

SITUATION: Corn and grain sorghum are our most important feed concentrates, and large quantities of both are also used by the industrial processor. The composition and total amount of protein, carbohydrate and oil in the corn kernel is under genetic control. Differences in digestability of the sorghum grain appear to have been established. Each of these sources of variability is of potential benefit to the livestock feeder. Waxy corn and sorghum, and high amylose corn are currently being used by the industrial processors. Other genetic types affecting the characteristics of the storage proteins, carbohydrates, and oil are known but their industrial potential has not been fully explored.

OBJECTIVE: To establish the extent of genetic control for variation in amount and quality of the seed protein, carbohydrate, and oils and to develop varieties of corn and grain sorghum having improved nutritional value and industrial processing characteristics.

RESEARCH APPROACHES:

A. Develop agronomically acceptable types having improved protein quality for both corn and grain sorghum.

B. Develop agronomically acceptable types with increased oil percentage which vary in degree of saturation of the component fatty acids.

C. To establish the basis for variation in digestability in corn and grain sorghum, and to incorporate the desirable characteristics into agronomically acceptable types.

D. Search for other genetic systems which may have potential for increasing the nutritional or industrial value of these two crops.

E. Coordinate with research in RPA's 307-A, 406, and 407.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: The value of the two crops will be increased.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
8	8

TITLE: New and improved food products. RPA 406.

SITUATION: Recent annual harvests have been more than 4 billion bushels of corn and 700 million bushels of sorghum. Out of this huge total over a third of a billion bushels were converted into food and industrial products. The ratio of foods to industrial products was roughly 2 to 1. The corn wet-milling and the corn dry-milling industries constitute the largest consumers of these grains after livestock feeding. The problems for research are to show the way to keep present markets and to find new applications for corn and sorghum.

Production technology is not alone in enjoying a high rate of change. The variety of food products, eating habits, nutritional quality, stability, purity, palatability, and convenience have their role in the sophisticated and complex science and technology of modern foods. Changes in food technology that affect the use of cereal grains are occurring at an increasing rate.

Increased research efforts are necessary to provide adequate data on the composition and properties of the grain and its constituents to permit conversion of grain into desired milled fractions for improved food products. Scientific and technological studies are required to develop new foods meeting tomorrow's standards of acceptability, nutrition, and convenience in order to expand food outlets for corn and sorghum grain.

The availability of large supplies of corn and sorghum grain at low prices is a major advantage favorable to their increased use in food products. This situation holds not only for their milled fractions, but also for refined starches, sirups, and sugars. New genetic varieties having higher contents of essential amino acids are being developed which are expected to increase the nutritive quality of corn food products. The new corn varieties with high quality protein should result in increased demand for both domestic use and export. Enzymatic conversion of cereal starches to sirups and sugars of diverse carbohydrate composition is expected to make corn and sorghum more important sources of high energy foods. To realize the full potential of new outlets an expanded research effort will be required on a broad front. Basic data on the physical and chemical properties will lay the foundation for new milling, refining, and conversion processes for the development of new food products.

OBJECTIVE: To increase food uses of corn and sorghum by providing chemical, physical, and biochemical properties of grain, grain components, and their derivatives, developing new processing technology, and developing new food products.

RESEARCH APPROACHES:

A. Determination of identity, amount, chemical structure, and properties of constituents of standard and genetic varieties of corn and sorghum.

B. Development of new and improved milling processes for corn and sorghum grain to obtain better yields and purity of fractions and constituents required for a wide variety of food products.

C. Development of new and improved enzymatic processes for converting starch into sweetening agents such as sirups, dextrose, fructose, and higher saccharides.

D. Development of highly nutritious, readily digestible foods suitable for infants and the elderly that are convenient and economical.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Increase the demand for corn and sorghum as raw materials for the dry milling and starch refining industries by: (1) Improving processing efficiency by supplying data on composition and properties of grain, grain fractions, and grain constituents; (2) Developing improved milling technology to produce final products at lower cost; (3) lowering the cost of converting starch into sirups and sugars, and (4) developing new low-cost food products meeting the need of large markets. New grain fractions, starch-derived sirups and sugars of higher sweetening power, and new economical and nutritious food products could require an additional 100 million bushels of grain. Savings in costs of production are estimated to be between 25 and 50 million dollars per year.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
32	35

RPA 407 -- New and improved feed and industrial products.

INTRODUCTION

A large quantity of corn and sorghum is available annually at stable prices. Current consumption by the mixed feed, dry-milling, and wet-milling industries is large and expanding. Genetic varieties are being rapidly developed, particularly of corn, which include types with higher quality protein, chemically different types of starch, and types with higher content of oil or protein. Realization of current prospects will offer opportunities for increased uses in feeds and industrial products.

Over 300 million bushels of these grains are dry or wet milled into flours, meals, feeds, starches and starch products, sugars, and sirups. Somewhat over a third of these products are used for feeds and industrial products.

Grain products are encountering increased competition from synthetic chemicals, particularly resins used for coatings, adhesives, sizes, and papermaking chemicals. Research to improve the performance of starches, flours, and their derived products will be necessary to meet specific industrial requirements. Research to provide essential information on composition and properties of milled fractions and refined products will form the basis of new processing technology and the development of new end products. Applied and development research is required to modify these grain products to better serve present applications and to discover new products and new applications.

TITLE: Development of feed products having increased palatability and nutritive quality for livestock. RPA 407-A.

SITUATION: Formulation of feeds has become an extremely complex operation as better information regarding animal nutritive requirements has been developed. The demand for commercial formula feeds is increasing. A limiting factor is the lack of reliable analysis of ingredients. Increased efficiency and consequent savings would result if better and more rapid methods of analysis were available.

Processing of feeds includes dry grinding, dry rolling, flaking, pelleting, expansion, and toasting. The objective is to improve feed efficiency. However, for some animals it appears that certain processes lead to detrimental effects. Very fine grinding and pelleting under some conditions are suspect in the occurrence of gastric ulcers in swine.

Inefficiency of cereal-based feeds in non-ruminant stock is due to low biological availability, particularly during early growth stages. Addition of enzymes that would render carbohydrates, fats, and proteins more available have promise for improving the efficiency of cereal feeds.

OBJECTIVE: To increase use of corn and sorghum as feeds by providing more accurate and rapid methods of analysis for grain constituents, improving processing technology, and discovering processes for making cereal products more digestible.

RESEARCH APPROACHES:

A. Determination of need for more accurate, more rapid, and more economical analytical methods for important constituents in cereal grains. Develop improved methods for assay of standard and new genetic varieties of grain.

B. Study the effect of grain processing procedures on biologically important constituents in grain as a means of correlating processing with adverse effects in animal. Develop economical processing methods that are suitable.

C. Study the effect of enzyme treatments of cereal grain feed products on availability of protein, fat, and carbohydrate content. Develop processes for the practical modification by enzymatic treatment.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Savings in feed costs for poultry and swine would accrue by elimination of unnecessary supplementation. Removal of cause of ulcers in swine feeding would reduce cost of pork production. Improved efficiency in use of cereals for poultry and swine would reduce cost of production. Reduction in feed costs would permit increased consumption by consumers and require more corn and sorghum to meet demands. A decrease in feed costs of one percent by eliminating over-supplementation to cereal feeds would mean a saving of around 40 million dollars per year. The elimination

of swine losses from ulcers is variable, but reduction of but a part of the losses now occurring would make savings of millions of dollars. Savings through increased digestibility of swine and poultry feed would be significant.

RESEARCH EFFORT:	T F RECOMMENDATION	
	1972	1977
	6	8

TITLE: Discovery and development of new chemical products from corn and sorghum starches and flours for use in large-volume industrial applications. RPA 407-B.

SITUATION; Cereal starches have not been used in large volume industrial applications except for ore beneficiation, oil-well drilling fluids, and textiles. In aluminum ore refining, starch and corn flour have been used somewhat interchangeably at the rate of about 32 pounds per ton of aluminum. Exploratory studies have indicated good potential of starch derivatives in refining other ores. High viscosity and stable additives are required for secondary oil recovery fluids. A number of starch-derived chemicals show good possibilities for this use. At one time starch was the principle sizing for warp yarns. It still is a big outlet but faces problems in disposal because its high B.O.D. leads to pollution of streams. Synthetic chemical sizes are making inroads such that industry has modified starch for this purpose but so far with only partial success. Recent research in the Northern Utilization Research and Development Division has revealed good probability for use of starch as a reinforcing agent and accelerator in making rubber products and also in making urethane-starch plastics, resins, and coatings. However, additional development studies are needed.

There is good reason to believe that starch can be modified by grafting on synthetic polymers to give flocculating agents for clarification of waste waters.

Other promising opportunities for increasing use of starch include new industrial uses for high-amylose corn starch; mass production of spores grown in corn sugar media for use as a bio-insecticide to control the Japanese beetle; and the more economical production of a microbial polysaccharide "xanthan" now being commercially produced.

OBJECTIVE: To modify cereal starches and flours by chemical and biochemical processes to obtain products with improved properties and to discover completely new applications of corn- and sorghum-derived products.

RESEARCH APPROACHES:

A. Development of practical processes for the incorporation of starch, flours, and their derivatives in rubber products.

B. Production of starch graft copolymers as flocculating, viscosity-improver, and adhesive agents by chemically combining starch with synthetic chemicals.

C. Development of starch-derived chemicals for use in making plastics and coatings.

D. Exploitation of high-amylose corn starches now commercially available as textile sizes, surface-coating, and film-packaging materials and adhesives.

E. Studies on improved fermentation processes to lower the cost of production of "xanthan," a microbial polysaccharide gum. (Developed at the Northern Division and now in commercial production and serving in applications that can afford current prices.)

F. Development of fermentative process for large-scale production of spores of Bacillus popilliae that can be used to establish endemic disease to control the Japanese beetle.

G. Studies to discover and evaluate new microbial polysaccharides having properties suitable for industrial uses.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Realization of the most probable goals sought under the approaches enumerated above would result in (a) retaining a number of traditional outlets for cereal products now meeting with increasing competition, (b) extending use of products in applications now known but which could be increased by making the products do a better job or lowering the cost of producing the cereal product, and (c) developing hitherto unknown applications such as rubber-reinforcing agents, starch plastics, and large-scale microbial insecticides. It is in the wholly new applications that greatest contributions could be made because of the large potential outlets if research efforts are successful.

A number of the potential benefits are difficult to estimate until sufficient preliminary data are at hand from exploratory research results. Benefits have been estimated as follows:

Starch in rubber	New use, 25 million lbs./yr.
Starch graft copolymers	New use, 40 million lbs./yr.
Starch plastics	New use, 25 million lbs./yr.
High-amylose starch	New use, 40 million lbs./yr.
Microbial polysaccharide (xanthan)	New use, 50 million lbs./yr.
New microbial polysaccharides	New use, 50 million lbs./yr.

Most of the estimated new uses also are expected to be achieved with savings in costs through use of cereal starch and flour products.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
36	38

TITLE: Conversion of corn and sorghum starches and flours into improved internal and surface-sizing agents, wet-strength agents, and adhesives for the paper industry. RPA 407-C.

SITUATION: The paper and board industry is the largest single consumer of starch and starch products in the U.S., requiring over one billion pounds annually. Starch as such and in its modified forms is used as an internal size, an external surface size, and adhesive in coating paper with clay and other pigments, and as an adhesive in making paper boxes. This large market is a traditional outlet. Starch has held its position here because of a number of technological improvements: New application processes and chemical or physical modifications which resulted in improved performance.

An additional advantage which starch products have over possible competitors is their low cost and availability in large quantity at rather stable prices. The wide variety of paper grades and their production for specific end uses in which performance requirements are continually changing is a major cause for the entrance of competing materials. Synthetic resins and other polymers have come into use largely because of their resistance to water and moisture or advantages in application. Synthetics have usually commanded higher prices than starch. In some cases their cost per unit of paper product is nearing that of starch because, per unit weight, they are more effective.

The problem for research in maintaining and improving the position of cereal products in the paper industry is to introduce new properties into cereal products. Better performance in improving quality of the paper product, savings in methods of application, and enabling production to be increased per unit of time are the most sought improvements.

OBJECTIVE: To provide starch and flour products that permit greater efficiency in paper product, that impart improved physical properties to paper, and that allow paper to meet more sophisticated end-use requirements.

RESEARCH APPROACHES:

A. Development of starch-based wet-web strengthening agents to permit paper, particularly newsprint, to be produced at faster rates.

B. Preparation and evaluation of experimental starch graft-copolymers to determine their effectiveness in bonding together wet pulp fibers to give wet tensile strength sufficient to withstand higher machine speeds without breaking of the wet paper.

C. Conduct studies on the effect of paper machine operating variables on the ultimate dry- and wet-tensile strength and water absorption of starch xanthate-treated paper.

D. Investigation of simplified and economical methods of perparing cationic starches and flours for use as internal size to improve dry tensile strength of paper.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: The cost of newsprint would be lowered by higher rates of production and by savings in the cost of adding high quality pulp to the ground-wood which is the major type of pulp used in newsprint. In laboratory experiments higher wet- and dry-tensile strengths and higher resistance to moisture have been found than with papers made on a 32-inch pilot fourdrinier machine. Achieving equal results on the pilot paper machine would make starch xanthate a better additive than any single additive in use today. Achievement of such an additive would almost certainly lead to commercial use. The use of corn and sorghum flour which is available at low price would permit savings in making lower grade paper. Economical processes for making cationic flours would increase the use of flours and lower the cost of producing paper.

The use of an effective wet-web strength cereal product applied at a 1 percent level (based on pulp) in all of the 3 million tons of newsprint produced in the U.S. per annum would require 30,000 tons of starch product and permit large savings in cost of newsprint production.

Success in developing practical conditions for use of starch xanthate to achieve wet- and dry-tensile strength increases along with resistance to moisture absorption could lead to the use of one-half million tons of starch xanthate. This is assuming an application of 2-1/2 percent addition to 20 million tons of paper.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
16	17

RPA 408 -- Quality maintenance in marketing.-

INTRODUCTION

Maintenance of quality of field crop commodities against the inroads of molds, insects, excessive moisture, chemical changes, and other quality deteriorating factors is important to minimize cost in storage and distribution. The resources required to produce lost commodities are wasted. In addition there are serious losses in end use quality that occur as a result of physical and chemical changes in transportation and storage of crops. The consumer receives a product less attractive than need be and in the end pays for merchandise not usable.

TITLE: Detecting and measuring quality factors. RPA 408-A.

SITUATION: Quality changes in corn and grain sorghum can be of physical, chemical or microbiological origin. They result from heat damage in the drying process, high moisture content, enzymatic changes and deterioration, and moisture - heat - insect - microorganism relationships. These changes effect product maintenance, food and feed quality, product grade and consumer acceptance. Such changes can cause a decrease in market quality which is reflected by a lower grade of the final product with a corresponding decrease in its marketing value. Furthermore, such changes can also affect consumer acceptance of the product. An additional change in quality is a loss in nutritive value either through the contamination by deleterious substances or the actual degradation of kernel components essential for adequate nutrition of the ultimate consumer. Many of the quality factors are presently determined by subjective methods which introduce bias. Other factors are determined by machines which are inefficient or yield results which do not accurately reflect the commercial value of the corn or grain sorghum. These include heat damage resulting from improper drying temperatures, deterioration due to high moisture content - insect - microorganism interrelationships and mechanical breakage.

OBJECTIVES: Determine the quality attributes of corn and grain sorghum and their products. Develop techniques, instruments and machines for rapid, objective evaluation of quality.

RESEARCH APPROACHES:

A. Develop practical and objective methods of determining quality attributes of corn and grain sorghum and their products.

B. Develop techniques, instruments and procedures for detecting and measuring chemical residues and other contaminants affecting quality.

C. Develop practical procedures and devices for sampling corn and grain sorghum and their products.

D. Coordinate research effort with RPA 207, 208-D, 209, and 308-D.

CHARACTER AND MAGNITUFE OF POTENTIAL BENEFITS: The results of this research should facilitate marketing transactions through more accurate description of products and more precise measurements of quality attributes.

RESEARCH EFFORTS:

T F RECOMMENDATION	
1972	1977
5	7

TITLE: Maintaining quality during storage, processing and transport. RPA 408-B.

SITUATION: Corn and grain sorghum are highly susceptible to damage by stored-grain insects from the time of harvest until final use. Milled and processed corn products also suffer heavy losses. These grains are largely used for animal feed and the insect infestation tends to be overlooked. Estimates of losses and cost of control for stored-grain insects during the period 1951-1960 were more than $300 million annually for corn and about $30 million for grain sorghum. As production increases to meet greater needs for food and feed these losses also increase and ways must be found to reduce them.

Insect infestations in stroed grain create a favorable environment for the growth of molds and bacteria. Recent findings show that stored-grain insects are carriers of avian leukosis, Salmonella, E. coli, and other micro-organisms. Further research is needed on the relationships between stored-grain insects and microorganisms, and on ways to break chains of transmission.

The traditional uses of insecticides and fumigants against stored-grain insects involve complex and ever changing situations. For example, alternate materials must be found as resistance develops to those in use. Each new insecticide requires extensive evaluation of effectiveness, residues, and mammalian toxicity. Therefore, research must continue on the development of safer, more effective conventional insecticidal control measures. It is also appropriate to give increased emphasis to the development of biological and physical control methods that will avoid the hazards of toxicity and chemical residues.

As a foundation for developing improved control measures, it is necessary to obtain more detailedinformation about the insects themselves. There are about 15 species that are responsible for most of the damage to stored grain and grain products. There are significant gaps in knowledge about the biology, ecology, physiology, and behavior of these insects. Adequate progress on developing new control measures cannot be made in the absence of increased basic research along the above lines.

Corn and grain sorghum are subject to deterioration during storage and transport. Development of new production and harvesting technology create new problems in storing and handling of these grains. Information is needed on the effect and control of microorganisms in storage. Methods are needed to detect quality deterioration during storage and transport. A better understanding of the exact moisture and humidity and temperature requirements for keeping quality is needed.

OBJECTIVE: To develop improved measures for controlling insects and mirco-organisms that attack stored corn and grain sorghum by the use of procedures that are effective, safe, and economical and to determine optimum environmental conditions for the storing and handling of corn and grain sorghum and their products during marketing.

RESEARCH APPROACHES:

A. Investigate the biology, ecology, physiology, and behavior of insects and of microorganisms that attack corn and grain sorghum, as a foundation for applied research.

B. Investigate the relationships between insects and microorganisms in stored corn and grain sorghum.

C. Investigate the influence of one microorganism on another under different exacting environmental conditions.

D. Develop improved, safe, economical conventional control procedures for insects and microorganisms that leave a minimum of chemical residues.

E. Develop biological and physical control measures for insects and micro-organisms that will avoid residues.

F. Develop methods of determining physiological deterioration of corn and grain sorghum and study the extent of this type of deterioration under different environmental conditions.

G. Coordinate these research studies with those under RPA 207 and 208-E.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Based on projected increases in production for 1980, a reduction of insect losses by one-half would bring about a savings of more than $300 million annually.

The development of safer control measures that would minimize or avoid chemical residues would provide tremendous health benefits that are difficult or impossible to quantify.

Research on developing optimum environmental conditions would lead to savings by the prevention of loss of quality and also to the protection of public health and welfare through safer products. There would be increased domestic and export sales because of better quality corn and grain sorghum and their products during marketing.

RESEARCH EFFORT:	T F RECOMMENDATION	
	1972	1977
	14	16

TITLE: Economic evaluation of quality maintenance and quality losses. RPA 408-C.

SITUATION: Corn and grain sorghum are subject to quality losses as they move through marketing, transportation, and storage facilities. These quality losses result in reduced economic value. Yet, quality maintenance as well as detection and evaluation of quality losses involves economic costs throughout the system.

In order to be feasible, quality measurement and maintenance methods must deliver benefits to the producer and the marketing system which are at least as great as the added costs involved.

There is need, therefore, to study the economics of existing and proposed quality measurement and maintenance systems.

OBJECTIVE: To investigate and evaluate the economic benefits and costs of quality measurement and maintenance in the corn and grain sorghum marketing system.

RESEARCH APPROACHES:

A. Study the economic gains associated with the reduction of quality losses in the corn and grain sorghum markets.

B. Measure the costs involved in securing these gains.

C. Evaluate the net benefits to producers, handlers, and users.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
2	3

TITLE: Improved grades and standards. RPA 501.

SITUATION: Grades and standards in the marketing system should provide meaningful communication with respect to quality of a product in relation to its price and use. Although present grades and standards serve useful purposes, they do not always make use of certain important quality factors. Determination of grain quality by present methods is frequently too slow, expensive and subjective. As a result the industry is strongly promoting an automated system of grain grading. The present system should be upgraded to recognize the importance and make use of protein content of grain as a grading factor, especially of grain sorghum. Other meaningful quality factors should be developed and established.

OBJECTIVE: To provide the basis for determining grades and standards that will effectively communicate value differences for varying gradations of quality.

RESEARCH APPROACHES:

A. Evaluate the effectiveness of existing grades and standards in serving the needs of sellers and buyers and for reflecting different gradations of quality which affect value and use.

B. Develop descriptive terminology for grades and standards which will characterize the different attributes of corn and grain sorghum and their products so as to facilitate communication between buyers and sellers.

C. Develop methods and establish a uniform system of grades and standards recognizing those characteristics which reflect value and affect use.

D. Coordinate with research under 408-A.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Development of instruments or machines for rapid, objective measurement of quality would lead to a reduction in the cost of inspection and grading. Improved communication through more precise terminology and methods for describing and assessing varying gradations of quality. Prices would more accurately reflect value and a more competitive position in marketing corn and grain sorghums in the world market would result. Decreased sampling and sampling analyses costs and more reliable inspection would be a major benefit.

RESEARCH EFFORT:

T F RECOMMENDATION	
1972	1977
2	3

RPA-504 -- Marketing efficiency

INTRODUCTION

Efficiency in marketing implies that products move from producers to processors to consumers with the maximum speed and technical efficiency consistent with low marketing costs and margins. Consequently, research in this general area for corn and grain sorghum focuses on two major categories. The first is the development and technical evaluation of marketing methods, systems, and equipment for handling and transport of these grains. The second is economic evaluation of the markets themselves including the costs and returns associated with various marketing methods, systems, and locational patterns of both production and utilization.

TITLE: Development and evaluation of improved methods, equipment, and systems for handling in the marketing channels. RPA 504-A.

SITUATION: Over one-half of the 4 billion bushels of corn and three-fourths of the 700 million bushels of grain sorghum are sold off the farm and move through at least one grain elevator or marketing facility. Export grain moves through at least five or six facilities and must be handled many times. New types of large capacity transport equipment require high grain handling rates, and under current conditions grain breakage is often increased. Research is needed to develop and evaluate design criteria for grain handling equipment that minimizes physical damage, particularly to corn.

Corn and grain sorghum continue to be harvested at high moistures and fast rates. This, together with the increase in the amount of grain moving to market at harvesttime, taxes conventional drying and conditioning systems. The pressing need is for more and better drying equipment and techniques, as well as improvements in handling and receiving corn and grain sorghum. Research is needed to design criteria for improved equipment and techniques.

The requirements of high-volume handling equipment also necessitates further study of rheological, physical, optical and electrical properties of corn and grain sorghum. From these studies, fundamental theories must be formulated for the development of new design criteria to minimize product damage.

Although losses have been reduced by transporting corn and grain sorghum in covered hopper-type rail cars, research is needed to reduce costs and losses when more conventional transport equipment is used. Seasonal peak demands in grain movement require better utilization of rail and highway equipment.

OBJECTIVE: To evaluate current technology and to develop more efficient work methods, techniques, equipment, and facilities for conditioning, drying, storing, handling and transporting corn and grain sorghum in the market channels.

RESEARCH APPROACHES:

A. Develop techniques and criteria for improved equipment to condition or dry corn and grain sorghum.

B. Develop criteria for modifying equipment to minimize physical damage of corn and grain sorghum.

C. Determine rheological, physical, optical and electrical properties of corn and grain sorghum.

D. Develop improved handling methods for receiving and shipping corn and grain sorghum at market facilities.

E. Develop design criteria for improved storages and equipment to provide recommended storage environments.

F. Evaluate existing transportation practices and equipment to determine product loss and damage, transport and maintenance costs with potentials for cost reduction.

G. Develop improved scheduling methods to increase utilization of transport equipment for seasonal peak demands.

H. Coordinate research studies with those in RPA 308-B.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Less expensive feed and food grain through reduced costs for physical marketing activities. Reduced physical loss in the product during storing, handling and transport. Maintenance of product quality during drying, handling and storing.

RESEARCH EFFORT:	T F RECOMMENDATION	
	1972	1977
	5	6

TITLE: Analysis of economic structure, behavior, and performance in markets. RPA 504-B.

SITUATION: Both the actual volume and the proportion of total corn and grain sorghum production moving through the marketing system is increasing. Today, 53 percent of the nation's corn production and 80 percent of the grain sorghum production is sold off the farm where produced. Compare this with 41 and 75 percent respectively only 6 years ago. Moreover, exports of feed grains have expanded at a faster rate than production in recent years. Significant adjustments are occurring in the location of feed grain production, in the location and size of livestock production and feeding enterprises, and in the technology of producing, harvesting, handling, transporting and marketing feed grains and related products. Federal programs continue to exert a major influence on the production, carryover, and prices of the major feed grains.

OBJECTIVE: To analyze the economic structure, behavior, and performance of the markets for corn and grain sorghum - with special emphasis on the costs of providing required marketing services, the interregional relationships in production and marketing, the economic linkages with the livestock and commercial feed sectors and the performance of export marketing functions.

RESEARCH APPROACHES:

A. Evaluate the overall structure and performance of corn and grain sorghum markets including studies of market prices costs, margins, practices, and facilities.

B. Examine the economic impacts of new and improved production and marketing technology on domestic and foreign markets.

C. Study and evaluate the economic impacts of ongoing and potential interregional shifts in the production of feed grains in relation to changes in the location and character of livestock production and marketing.

D. Coordinate the research in this area with the work undertaken in RPA 309-B.

CHARACTER AND MAGNITUDE OF POTENTIAL BENEFITS: Economic analysis on the changing marketing system for corn and grain sorghums will be extremely useful in the planning and execution of federal agricultural policy and programs, in the evaluation of current and future shifts in the character and location of production and marketing functions in both feed grains and livestock, and the impact of these changes on farm and nonfarm income and profits. Studies of this type will be valuable for gauging the performance of the firms and other institutions operating in this sector of the economy.

RESEARCH EFFORT:	T F RECOMMENDATION	
	1972	1977
	9	11